Acerca de este libro

Esta es una copia digital de un libro que, durante generaciones, se ha conservado en las estanterías de una biblioteca, hasta que Google ha decidido escanearlo como parte de un proyecto que pretende que sea posible descubrir en línea libros de todo el mundo.

Ha sobrevivido tantos años como para que los derechos de autor hayan expirado y el libro pase a ser de dominio público. El que un libro sea de dominio público significa que nunca ha estado protegido por derechos de autor, o bien que el período legal de estos derechos ya ha expirado. Es posible que una misma obra sea de dominio público en unos países y, sin embargo, no lo sea en otros. Los libros de dominio público son nuestras puertas hacia el pasado, suponen un patrimonio histórico, cultural y de conocimientos que, a menudo, resulta difícil de descubrir.

Todas las anotaciones, marcas y otras señales en los márgenes que estén presentes en el volumen original aparecerán también en este archivo como testimonio del largo viaje que el libro ha recorrido desde el editor hasta la biblioteca y, finalmente, hasta usted.

Normas de uso

Google se enorgullece de poder colaborar con distintas bibliotecas para digitalizar los materiales de dominio público a fin de hacerlos accesibles a todo el mundo. Los libros de dominio público son patrimonio de todos, nosotros somos sus humildes guardianes. No obstante, se trata de un trabajo caro. Por este motivo, y para poder ofrecer este recurso, hemos tomado medidas para evitar que se produzca un abuso por parte de terceros con fines comerciales, y hemos incluido restricciones técnicas sobre las solicitudes automatizadas.

Asimismo, le pedimos que:

+ *Haga un uso exclusivamente no comercial de estos archivos* Hemos diseñado la Búsqueda de libros de Google para el uso de particulares; como tal, le pedimos que utilice estos archivos con fines personales, y no comerciales.

+ *No envíe solicitudes automatizadas* Por favor, no envíe solicitudes automatizadas de ningún tipo al sistema de Google. Si está llevando a cabo una investigación sobre traducción automática, reconocimiento óptico de caracteres u otros campos para los que resulte útil disfrutar de acceso a una gran cantidad de texto, por favor, envíenos un mensaje. Fomentamos el uso de materiales de dominio público con estos propósitos y seguro que podremos ayudarle.

+ *Conserve la atribución* La filigrana de Google que verá en todos los archivos es fundamental para informar a los usuarios sobre este proyecto y ayudarles a encontrar materiales adicionales en la Búsqueda de libros de Google. Por favor, no la elimine.

+ *Manténgase siempre dentro de la legalidad* Sea cual sea el uso que haga de estos materiales, recuerde que es responsable de asegurarse de que todo lo que hace es legal. No dé por sentado que, por el hecho de que una obra se considere de dominio público para los usuarios de los Estados Unidos, lo será también para los usuarios de otros países. La legislación sobre derechos de autor varía de un país a otro, y no podemos facilitar información sobre si está permitido un uso específico de algún libro. Por favor, no suponga que la aparición de un libro en nuestro programa significa que se puede utilizar de igual manera en todo el mundo. La responsabilidad ante la infracción de los derechos de autor puede ser muy grave.

Acerca de la Búsqueda de libros de Google

El objetivo de Google consiste en organizar información procedente de todo el mundo y hacerla accesible y útil de forma universal. El programa de Búsqueda de libros de Google ayuda a los lectores a descubrir los libros de todo el mundo a la vez que ayuda a autores y editores a llegar a nuevas audiencias. Podrá realizar búsquedas en el texto completo de este libro en la web, en la página `http://books.google.com`

This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

https://books.google.com

J1
9280
.129
.21
v.36
1917

ANNEX LIB.

Library of

Princeton University.

Elizabeth Foundation.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

PROCEEDINGS

OF THE

AMERICAN INSTITUTE

OF

ELECTRICAL ENGINEERS

Vol. XXXVI Number 1

JANUARY, 1917

21 Wo6

UNIVERSITY LIBRARY
PRINCETON, N. J.

Pittsburgh Meeting, January 12, 1917
Midwinter Convention, February 14, 15 and 16, 1917

Digitized by Google

MIDWINTER CONVENTION

FEBRUARY 14, 15, 16, 1917

The Fifth Midwinter Convention of the Institute will be held in the Engineering Societies Building, 25-33 West 39th Street, New York, on Wednesday, Thursday and Friday, February 14, 15, and 16, 1917.

The technical program, printed elsewhere in this issue, contains an unusually interesting list of papers on a wide variety of subjects, insuring some topic of particular interest to every member.

ADVANCE NOMINATIONS

The attention of members is called to the notice on page 3 of this issue regarding advance nominations for Institute officers for 1917-1918. To be valid, such advance nominations must be received by the Secretary not later than January 25, 1917.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 1

JANUARY, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Institute Meeting in Pittsburgh, January 12, 1917 - 1
A. I. E. E. Midwinter Convention, February 14-16, 1917 - 2
Nominations For Institute Officers For 1917-18 - 3
Future Institute Meetings - 4
Future Section Meetings - 4
A. I. E. E. Directors' Meeting, Boston, Mass., December 8, 1916 - 4
Annual Meeting of Society of Automobile Engineers - 5
A. I. E. E. Meeting in Boston, December 9, 1916 - 5
Presentation of The John Fritz Medal - 6
Topographical Map of United States - 12
Research Fellowships, University of Illinois - 12
Past Section Meetings - 12
Past Branch Meetings - 14
Personal - 16
Recommended for Transfer, November 28, 1916 - 16
Transferred to the Grade of Fellow, December 8, 1916 - 17
Transferred to the Grade of Member, December 8, 1916 - 17
Members Elected, December 8, 1916 - 17
Associates Elected, December 8, 1916 - 17
Application for Election - 20
Students Enrolled, December 8, 1916 - 21
Employment Bulletin - 22
Accessions to Library - 24

Section II.—Papers, Discussions and Reports

Regenerative Braking of Electric Vehicles, by R. E. Hellmund, Pittsburgh, January 12, 1917 - 1
Investigations of Suspension Insulator Deterioration, by J. E. Woodbridge, San Francisco, November 24, 1916 - 57
Ceramics in Relation to the Durability of Porcelain Suspension Insulators, by Harris J. Ryan, San Francisco, November 24, 1916 - 61
Experiments on Porcelain Insulator Units, by J. Cameron Clark, San Francisco, November 24, 1916 - 77
The Future of Water Power in the United States, by Charles W. Comstock, Denver, February 19, 1916 - 91

Copyright 1917. By A. I. E. E.
Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

561719

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,
Under the Auspices of the Meetings and Papers Committee.
GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 2

FEBRUARY, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

A. I. E. E. Midwinter Convention - - - - - - - - - - - - - - - - 31
Future Institute Meetings - - - - - - - - - - - - - - - - - - 33
Future Section Meetings - - - - - - - - - - - - - - - - - - - 33
A. I. M. E., New York Meeting - - - - - - - - - - - - - - - - 34
Year Book, 1917 - 34
John Fritz Medal - 34
Directors' Meeting, Pittsburgh, January 12, 1917 - - - - - - - - - - 34
Henry Gordon Stott - 35
Florida Engineering Society - - - - - - - - - - - - - - - - - 37
A. I. E. E., Pittsburgh Meeting, January 12, 1917 - - - - - - - - - 37
Past Section Meetings - - - - - - - - - - - - - - - - - - - 37
Past Branch Meetings - 38
Members Elected, January 12, 1917 - - - - - - - - - - - - - - - 40
Transferred to the Grade of Member January 12, 1917 - - - - - - - - - 40
Recommended for Transfer, January 4, 1917 - - - - - - - - - - - - 40
Associates Elected, January 12, 1917 - - - - - - - - - - - - - - 40
Applications for Election - - - - - - - - - - - - - - - - - - 45
Students Enrolled, January 12, 1917 - - - - - - - - - - - - - - 47
Personal - 48
Employment Department- 49
Accessions to Library - 52

Section II.—Papers, Discussions and Reports

Internal Temperatures of A-C. Generators, by Ralph Kelly, New York, February 14, 1917 - 103
Reactors in Hydroelectric Stations, by J. Allen Johnson, New York, February 14, 1917 - 119
Protection of Transformer Neutrals Against Destructive Transient Disturbances, by Max H. Collbohm, New York, February 14, 1917 - - - - - - - - - - - - - - - 139
Corona and Rectification in Hydrogen, by J. W. Davis and C. S. Breese, New York, February 15, 1917 - 143
The Electric Strength of Air VII, by J. B. Whitehead and W. S. Brown, New York, February 15, 1917 - 159
Oscillating Current Circuits by the Method of Generalized Angular Velocities, by V. Bush, New York, February 15, 1917 - - - - - - - - - - - - - - - - - - - 189
Transient Conditions in Asynchronous Induction Machines and Their Relation to Control, by R. E. Hellmund, New York, February 16, 1917 - - - - - - - - - - - - 205
Performance of Polyphase Induction Motors Under Unbalanced Secondary Conditions, by A. A. Gazda, New York, February 16, 1917 - - - - - - - - - - - - - - 223
Industrial Controllers with Particular Reference to the Control of D-C. Motors, by H.D. James, New York, February 16, 1917 - - - - - - - - - - - - - - - - 233
Analysis of Starting Characteristics of D-C. Motors, by K. L. Hansen, New York, February 16, 1917 - 255
The Effect of Current-Limiting Reactors in Steam Turbine Stations Under Short-Circuit Conditions, by Paul B. Juhnke, New York, February 14, 1917 - - - - - - - - - 281

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 3

MARCH, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

A. I. E. E. Meeting, Chicago, March 9, 1917 - - - - - - - - - - - - - 59
A. I. E. E. Meeting, Schenectady, April 13, 1917 - - - - - - - - - - - - 61
A. I. E. E. Annual Convention - - - - - - - - - - - - - - - - 61
Coming Section Meetings - - - - - - - - - - - - - - - - - 61
Directors Meeting, New York, February 15, 1917 - - - - - - - - - - - 62
Engineers in National Defense - - - - - - - - - - - - - - - - 62
A. I. E. E. Midwinter Convention - - - - - - - - - - - - - - - 65
Past Section Meetings - - - - - - - - - - - - - - - - - - 67
Past Branch Meetings - - - - - - - - - - - - - - - - - - 68
Reinstated to Membership, February 15, 1917 - - - - - - - - - - - - 70
Members Elected February 15, 1917 - - - - - - - - - - - - - - 70
Transferred to Grade of Member February 15, 1917 - - - - - - - - - - - 70
Recommended for Transfer February 6, 1917 - - - - - - - - - - - - 71
Associates Elected, February 15, 1917 - - - - - - - - - - - - - - 71
Applications for Election - - - - - - - - - - - - - - - - - - 74
Students Enrolled - 76
Personal - 77
Accessions to Library - - - - - - - - - - - - - - - - - - 78
Employment Department - - - - - - - - - - - - - - - - - - 80

Section II.—Papers and Reports

Electrical Machinery Tests and Specifications Based on Modern Standards, by H. M. Hobart, Toronto, Can., September 22, 1916 - - - - - - - - - - - - - - 291
Relays for High-Tension Lines, by Philip Torchio, Chicago, Ill., March 9, 1917 - - - - - 321
The Protective Relay Equipment of the System of the Commonwealth-Edison Company, by R. F. Schuchardt, Chicago, Ill., March 9, 1917 - - - - - - - - - - - - - 337

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

(RECAP)

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 4

APRIL, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

A. I. E. E. Meeting in Schenectady, April 13, 1917 - - - - - - - - - - - - 89
A. I. E. E. May Meeting - - - - - - - - - - - - - - - - - - 90
A. I. E. E. Annual Convention, June 26-29, 1917 - - - - - - - - - - - - 90
Future Section Meetings - - - - - - - - - - - - - - - - - - 90
A. I. E. E. Meeting in Chicago, March 9, 1917 - - - - - - - - - - - - 91
Directors' Meeting, Chicago, March 9, 1917 - - - - - - - - - - - - 91
A. I. E. E. Nominations - - - - - - - - - - - - - - - - - - 92
Report of Committee of Tellers on Nomination Ballots - - - - - - - - - - 92
United Engineering Society (Extracts from Presidents' Annual Report) - - - - - - 93
Library Report for 1916 - - - - - - - - - - - - - - - - - - 94
Harrison W. Craver Appointed Library Director - - - - - - - - - - - - 94
John Fritz Medal Book - - - - - - - - - - - - - - - - - - 95
Past Section Meetings - - - - - - - - - - - - - - - - - - 95
Past Branch Meetings - - - - - - - - - - - - - - - - - - 97
Members Elected March 9, 1917 - - - - - - - - - - - - - - - - 99
Associates Re-elected March 9, 1917 - - - - - - - - - - - - - - 100
Member Re-elected March 9, 1917 - - - - - - - - - - - - - - - 100
Associates Elected March 9, 1917 - - - - - - - - - - - - - - - 100
Recommended for Transfer - - - - - - - - - - - - - - - - 105
Transferred to the Grade of Fellow March 9, 1917 - - - - - - - - - - 106
Transferred to the Grade of Member March 9, 1917 - - - - - - - - - - 106
Applications for Election - - - - - - - - - - - - - - - - - 106
Students Enrolled March 9, 1917 - - - - - - - - - - - - - - - 108
Obituary - 109
Personal - 109
Accessions to Library - - - - - - - - - - - - - - - - - - 110
Employment Department - - - - - - - - - - - - - - - - - 111

Section II.—Papers and Reports

Cooling of Oil Immersed Transformer Windings after Shut-Down. By V. M. Montsinger,
Schenectady, N. Y., April 13, 1917 - - - - - - - - - - - - - - 351
Report of the Joint Rubber Insulation Committee—1916 - - - - - - - - - - 371

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 5

MAY, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Annual Business Meeting and Edison Medal Presentation - - - - - - - - - - 123
A. I. E. E. Annual Convention June 26-29 - - - - - - - - - - - - - - 123
Amendment to By-Laws - - - - - - - - - - - - - - - - - - 124
The Engineering Societies in National Defense, by Gano Dunn - - - - - - - - 124
Memorial to the Late Prof. Silvanus P. Thompson, D.Sc. F.R.S. - - - - - - - - 126
Greetings from French Engineers - - - - - - - - - - - - - - - - 126
The Problem of Selecting Papers, by L. T. Robinson - - - - - - - - - - 127
Future Section Meetings - - - - - - - - - - - - - - - - - - 127
Directors' Meeting New York, April 13, 1917 - - - - - - - - - - - - 128
Past Section Meetings - - - - - - - - - - - - - - - - - - 128
Past Branch Meetings - - - - - - - - - - - - - - - - - - 130
Associates Elected April 13, 1917 - - - - - - - - - - - - - - - 132
Member Elected April 13, 1917 - - - - - - - - - - - - - - - - 138
Associates Re-Elected April 13, 1917 - - - - - - - - - - - - - - 139
Members Re-Elected April 13, 1917 - - - - - - - - - - - - - - - 139
Recommended for Transfer - - - - - - - - - - - - - - - - - 139
Transferred to Grade of Fellow, April 13, 1917 - - - - - - - - - - - - 140
Transferred to Grade of Member, April 13, 1917 - - - - - - - - - - - - 140
Applications for Election - - - - - - - - - - - - - - - - - - 140
Students Enrolled April 13, 1917 - - - - - - - - - - - - - - - - 141
Obituary - 142
Personal - 142
Accessions to Library - - - - - - - - - - - - - - - - - - 143
Employment Department - - - - - - - - - - - - - - - - - - 144

Section II.—Papers and Reports

Expansion Effects as a Cause of Deterioration in Suspension Type Insulators. By J. A. Brundige, Hot Springs, Va., June 27, 1917 - - - - - - - - - - - - - - - 391
The Insulator Situation. By W. D. Peaslee, Hot Springs, Va., June 27, 1917 - - - - - 401
Problems of Operation and Maintenance of Underground Cables. By John L. Harper, Hot Springs, Va., June 27, 1917 - - - - - - - - - - - - - - - - - 409

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 6

JUNE, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Special Meeting of A. I. E. E., New York, June 27-28, 1917 - - - - - - - - - 155
Annual Meeting and Edison Medal Presentation - - - - - - - - - - - 156
Report of Committee of Tellers on Election - - - - - - - - - - - - 157
The Engineering Council - - - - - - - - - - - - - - - - - 158
Directors Meeting, May 18, 1917 - - - - - - - - - - - - - - - 159
Rules Governing Presentation and Discussion of Papers at Institute Meetings - - - - 160
Valuable Gift to Library - - - - - - - - - - - - - - - - - 160
Past Section Meetings - - - - - - - - - - - - - - - - - - 161
Past Branch Meetings - - - - - - - - - - - - - - - - - - 162
Associates Elected, May 18, 1917 - - - - - - - - - - - - - - - 163
Associates Re-Elected, May 18, 1917 - - - - - - - - - - - - - - 168
Members Elected, May 18, 1917 - - - - - - - - - - - - - - - 168
Fellow Elected, May 18, 1917 - - - - - - - - - - - - - - - - 169
Recommended for Transfer - - - - - - - - - - - - - - - - - 169
Transferred to Grade of Fellow, May 18, 1917 - - - - - - - - - - - - 169
Transferred to Grade of Member, May 18, 1917 - - - - - - - - - - - - 169
Applications for Election - - - - - - - - - - - - - - - - - 170
Students Enrolled, May 18, 1917 - - - - - - - - - - - - - - - 171
Personal - 171
Accessions to Library - - - - - - - - - - - - - - - - - - 171
Employment Department - - - - - - - - - - - - - - - - - - 173

Section II.—Papers and Reports

Illumination of the Panama-Pacific International Exposition. By W. D'A. Ryan, Schenectady N. Y., May 4, 1916 - 415
Fundamentals of High-Tension Cable Joints. By D. W. Roper, Hot Springs, Va., June 27, 1917 441
The Influence of Dielectric Losses on the Rating of High-Tension Underground Cables. By A. F. Bang and H. C. Louis, Hot Springs, Va., June 27, 1917 - - - - - - - - 449
Insulation Characteristics of High-Voltage Cables. By W. S. Clark and G. B. Shanklin, Hot Springs, Va., June 27, 1917 - - - - - - - - - - - - - - - - - - 465
Present Practise in the Design and Manufacture of High-Tension Insulators. By A. O. Austin, Hot Springs, Va., June 27, 1917 - - - - - - - - - - - - - - - - 513
Economical Combination of Water Power and Steam Plants, and a Convenient Method of Solution. By H. St. Clair Putnam, Hot Springs, Va., June 28, 1917 - - - - - - 531
Board of Directors Report for Fiscal Year Ending April 30, 1917 - - - - - - - - 549

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 7

JULY, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Special Meeting of A. I. E. E., New York, June 27-28, 1917 - - - - - - - - - 181
Director's Meeting, June 28, 1917 - - - - - - - - - - - - - - - - 182
Dinner to President-Elect Rice - - - - - - - - - - - - - - - - 183
Greetings from the Institution of Electrical Engineers - - - - - - - - - 183
National Committee on Gas and Electric Service - - - - - - - - - - - 184
Presentation of the John Fritz Medal to Henry Marion Howe - - - - - - - - 185
Third National Exposition of Chemical Industries - - - - - - - - - - 186
Past Section Meetings - - - - - - - - - - - - - - - - - - - 186
Past Branch Meetings - - - - - - - - - - - - - - - - - - - 187
Associates Elected, June 28, 1917 - - - - - - - - - - - - - - - - 188
Associates Re-Elected, June 28, 1917 - - - - - - - - - - - - - - - 192
Members Elected, June 28, 1917 - - - - - - - - - - - - - - - - 192
Fellow Elected, June 28, 1917 - - - - - - - - - - - - - - - - 192
Recommended for Transfer - - - - - - - - - - - - - - - - - 192
Transferred to Grade of Member, June 28, 1917 - - - - - - - - - - - 193
Transferred to Grade of Fellow, June 28, 1917 - - - - - - - - - - - - 193
Applications for Election - - - - - - - - - - - - - - - - - 193
Students Enrolled, June 28, 1917 - - - - - - - - - - - - - - - - 194
Obituary - 194
Personal - 194
Accessions to the United Engineering Society Library - - - - - - - - - - 195
Employment Department - - - - - - - - - - - - - - - - - 202

Section II.—Papers and Reports

Forms of Electric Power Best Suited for the Various Loads Encountered in the Operation of Bituminous Coal Mines. By R. L. Kingsland - - - - - - - - - - - 567
A New Electric Mine Hoist at Butte, Montana. By R. S. Sage - - - - - - - - - 573
Annual Report of Technical Committees - - - - - - - - - - - - - - 889

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 8

AUGUST, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Florida Engineering Society - - - - - - - - - - - - - - - - - - 211

Past Section Meetings - 211

Recommended for Transfer - - - - - - - - - - - - - - - - - - 212

Applications for Election - - - - - - - - - - - - - - - - - - 212

Addresses Wanted - 213

Personal - 213

Obituary - 213

Accessions to the United Engineering Society Library - - - - - - - - - - 214

Employment Department - - - - - - - - - - - - - - - - - - - 220

Section II.—Papers and Reports

The Engineer's Destiny, President's Address, by H. W. Buck, New York, June 27, 1917 - 629

Address by President-Elect, E. W. Rice, Jr., New York, June 27, 1917 - - - - - 635

Transmission Line Design. By F. K. Kirsten. (Presented by publication only.) - - - 641

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904, under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,
Under the Auspices of the Meetings and Papers Committee.
GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico Hawaii and the Phillipines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 9

SEPTEMBER, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Institute Meeting in Philadelphia, October 8, 1917 - - - - - - - - - - - - - - - - 227
A. I. E. E. Directors' Meeting, August 14, 1917 - - - - - - - - - - - - - - - - 227
Engineering Council - 228
Past Section Meetings - 228
Associates Elected, August 14, 1917 - 229
Members Elected, August 14, 1917 - 232
Transferred to Grade of Fellow August 14, 1917 - - - - - - - - - - - - - - - - 232
Transferred to Grade of Member, August 14, 1917 - - - - - - - - - - - - - - - - 232
Recommended for Transfer - 232
Applications for Election - 233
Students Enrolled - 233
Addresses Wanted - 233
Personal - 234
Accessions to the United Engineering Society Library - - - - - - - - - - - - - 234
Employment Department - 238

Section II.—Papers and Reports

Modern Physics, by R. A. Millikan, New York, February 15, 1917 - - - - - - - - - - 695
Design, Construction and Tests of an Artificial Power Transmission Line for the Telluride Power Company of Provo, Utah, by George H. Gray. (Presented by publication only) - - - - 713

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904. under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 10

OCTOBER, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Institute Meeting, Philadelphia, Pa., October 8, 1917 - - - - - - - - - - 247
The Engineering Council - 247
Examination for Assistant Civil Engineer, United States Navy - - - - - - - - 250
New Cooperative Courses at M. I. T. - - - - - - - - - - - - - - - - 250
Past Section Meetings - 250
Recommended for Transfer - - - - - - - - - - - - - - - - - - - 251
Applications for Election - 251
Personal - 251
Obituary - 252
Accessions to United Engineering Society Library - - - - - - - - - - - 252
Employment Department - 254

Section II.—Papers and Reports

Industrial Research and the Colleges, by A. E. Kennelly, Philadelphia, Pa., October 8, 1917 - - 757
Industrial Research and Its Relation to University and Governmental Research, by C. E. Skinner, Philadelphia, Pa., October 8, 1917 - - - - - - - - - - - - 765

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904 under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,
Under the Auspices of the Meetings and Papers Committee.
GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 11

NOVEMBER, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

nstitute Meeting in New York, November 9, 1917 - - - - - - - - - - - - 263
The Engineering Foundation and the National Research Council - - - - - - - - - 263
A. I. E. E. Meeting in Philadelphia, October 8, 1917 - - - - - - - - - - - 267
A. I. E. E. Directors Meeting, Philadelphia, October 8, 1917 - - - - - - - - - 268
The Work of the Meetings and Papers Committee - - - - - - - - - - - 269
Illuminating Engineering Society Meeting - - - - - - - - - - - - 271
Electrical Engineers Nominated for Commissions in Navy - - - - - - - - - - 271
Government Service - - - - - - - - - - - - - - - - - - 272
The Engineering Council - - - - - - - - - - - - - - - - - 273
Future Section Meetings - - - - - - - - - - - - - - - - - 273
Past Section Meetings - - - - - - - - - - - - - - - - - 273
Past Branch Meetings - - - - - - - - - - - - - - - - - 274
Associates Elected, October 8, 1917 - - - - - - - - - - - - - - 275
Associates Re-elected, October 8, 1917 - - - - - - - - - - - - - - 277
Members Elected, October 8, 1917 - - - - - - - - - - - - - - - 277
Recommended for Transfer - - - - - - - - - - - - - - - - 277
Transferred to Grade of Fellow, October 8, 1917 - - - - - - - - - - - 277
Transferred to Grade of Member, October 8, 1917 - - - - - - - - - - - 277
Applications for Election - - - - - - - - - - - - - - - - 278
Students Enrolled - - - - - - - - - - - - - - - - - - 279
Addresses Wanted - - - - - - - - - - - - - - - - - - 279
Personal - 280
Obituary - 281
Accessions to United Engineering Society Library - - - - - - - - - - - 282
Employment Department - - - - - - - - - - - - - - - - - 285

Section II.—Papers and Reports

An Experimental Method of Obtaining the Solution of Electrostatic Problems with Notes on High-Voltage Bushing Design, by C. W. Rice, New York, November 9, 1917 - - - - - 777

Industrial Research with Some Notes Concerning Its Scope in the Bell Telephone System, by F. B. Jewett, Philadelphia, Pa., October 8, 1917 - - - - - - - - - - - - 925

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904 under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico, Hawaii and the Philippines; $11.00 to Canada and $12.00 to all other countries. Single copies $1.00. Volumes begin with the January issue.

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month.

Digitized by Google

PROCEEDINGS

OF THE

American Institute of Electrical Engineers

Vol. XXXVI
Number 12

DECEMBER, 1917

Per Copy $1.00
Per Year $10.00

TABLE OF CONTENTS

Section I.—Institute Affairs

Institute Meeting in New York, December 14, 1917 - 295
Annual Meeting of the A. S. M. E. - 295
Meeting of the Institute of Radio Engineers - 296
Future Section Meetings - 296
Reception to the American Society of Civil Engineers - 296
Scope of Future A. I. E. E. Meetings to be Extended - 296
Nominations for Institute Officers for 1918-19 - 297
The Engineering Society Club of Hawaii - 297
A. I. E. E. Honor Roll - 298
Membership Service Classification - 306
A. I. E. E. Directors' Meeting, New York, November 9, 1917 - 306
A. I. E. E. Meeting in New York, November 9, 1917 - 307
Government Service - 308
Past Section Meetings - 309
Past Branch Meetings - 310
Associates Elected, November 9, 1917 - 313
Associates Reelected, November 9, 1917 - 313
Members Elected, November 9, 1917 - 313
Transferred to the Grade of Member, November 9, 1917 - 313
Recommended for Transfer - 314
Applications for Election - 314
Students Enrolled, November 9, 1917 - 315
Personal - 316
Obituary - 317
Accessions to the United Engineering Society Library - 317
Employment Bulletin - 320

Section II.—Papers and Reports

Annual Load Relief Map, Peak Load and Load Factor Analysis, by Wm. LeRoy Robertson. Presented by publication only - 941
Corona Tests at High Altitude, by B. F. Jakobsen, Section Meeting, San Francisco, Cal., January 25, 1918 - 949
Phenomena Accompanying Transmission With Some Types of Star Transformer Connections by Lloyd N. Robinson, New York, December 14, 1917 - 967
Magnetic Flux Distribution of Annular Steel Laminae, by A. E. Kennelly and P. L. Alger, New York, December 14, 1917 - 999

Copyright 1917. By A. I. E. E.

Permission is given to reprint any paper after its date of presentation, provided proper credit is given.

Entered as matter of the second class at the Post office, New York, N. Y., December 17, 1904 under the Act of Congress, March 3, 1879.

Digitized by Google

Published monthly by the A. I. E. E. at 33 West 39th Street, New York,

Under the Auspices of the Meetings and Papers Committee.

GEORGE R. METCALFE, Editor.

Subscription. $10.00 per year to United States, Mexico, Cuba, Porto Rico Hawaii and the Philippines; $11.00 to Canada and $12.00 to all other countries Single copies $1.00. Volumes begin with the January issue

Changes of advertising copy should reach this office by the 15th of the month for the issue of the following month

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI JANUARY, 1917 Number 1

INSTITUTE MEETING IN PITTSBURGH JANUARY 12, 1917

The 328th meeting of the American Institute of Electrical Engineers will be held in Pittsburgh, Pa., January 12, 1917, under the auspices of the Pittsburgh Section and the Traction and Transportation Committee.

The official headquarters of the Institute during the meeting will be in the Fort Pitt Hotel where the technical sessions and all other meetings will be held. The registration office will be open at 9:00 a.m. and members and guests are requested to register promptly.

The morning and afternoon will be devoted to various committee meetings, to a number of inspection trips, and to the Board of Directors meeting. At 6:30 p.m. an informal dinner will be served in the English Room of the Hotel to members and guests in attendance. The technical session will be held in the English Room at 8:00 p. m., the general subject of the meeting being "Regenerative Braking".

The Engineers Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, has extended the privilege of its rooms to members and guests of the A. I. E. E. attending this meeting.

PROGRAM

Committee Meetings

Standards Committee, 10:00 a. m.

Meetings and Papers Committee, 2:00 p. m.

Finance Committee, 3:00 p. m.

The Membership Committee, Traction and Transportation Committee, and Industrial Power Committee, will also hold meetings during the day as specified in notices to the committee members.

Board of Directors

Luncheon at 1:00 p. m.

Regular monthly meeting at 3:30 p.m.

Inspection Trips

Inspection trips to industrial plants, 10:00 a. m. to 5:00 p. m. Information in regard to these trips can be secured at the registration office.

Technical trips which have been planned are as follows:

Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Duquesne Light Company, Brunot Island Power Plant.

Pittsburgh Railways Company, Homewood Shops.

Pittsburgh Railways Company, Taggart Street Substation.

Bell Telephone Company, Grant Exchange.

Two non-technical trips have been arranged as follows:

Carnegie Institute Museum.

H. J. Heinz Company.

The Pittsburgh Railways Company will furnish special cars for the trips to its plants.

Informal Dinner

An informal table d'hote dinner will be served to members and guests in the English Room of the Fort Pitt Hotel at 6:30 p. m., price $1:50 per cover.

Digitized by Google

Dinner tickets should be purchased at registration headquarters as early as possible.

TECHNICAL SESSION

8:00 p. m.

A paper will be presented on *Regenerative Braking of Electric Vehicles*, by R. E. Hellmund, of the Westinghouse Electric & Manufacturing Co.

This paper is an exhaustive study of regenerative control as applicable to various systems of electric railways, and in view of the wide possibilities which exist for successful regeneration the subject of regenerative braking is rapidly assuming great commercial importance. Its practical advantages in electric railway work and for heavy railroads, as well as in various other fields, such as steel mills, etc., make it of special interest to engineers engaged in railway work and other applications of electric power.

The paper is published in this issue of PROCEEDINGS and advance copies are available upon application to Institute headquarters.

FORT PITT HOTEL

All correspondence in regard to hotel reservations should be addressed to the hotel management. Hotel rates on the European plan are as follows:

	Without bath	With bath
Single Rooms.....	$1.50	$2.50 to 4.00
Double Rooms...	§$2.50 and 3.00	$3.50 to 6.00

A. I. E. E. MIDWINTER CONVENTION FEBRUARY 14-16, 1917

The Fifth Midwinter Convention of the American Institute of Electrical Engineers will be held in the Engineering Societies Building, 33 West 39th Street, New York, February 14 to 16, 1917. There will be five technical sessions, one each morning and on Wednesday and Friday afternoon. Thursday evening there will be a lecture under the auspices of the Electrophysics Committee. Wenesday evening and Thursday afternoon will be devoted to social features, inspection trips and other entertainment features which are being arranged by the Entertainment Committee and the Technical Excursion Committee. The technical program includes a diversity of subjects which will insure wide interest.

Registration

The registration office will be in the lobby of the Engineering Societies Building, and in order to facilitate handling of mail telegrams, inquiries, etc., members and guests in attendance are requested to register promptly upon their arrival.

PROGRAM

Wednesday, February 14

The convention will open with an address by President H. W. Buck, and will be followed by a paper under the auspices of the Standards Committee entitled *Internal Temperatures of A-C. Generators*, by Ralph Kelly.

AFTERNOON SESSION

Two papers will be presented at the afternoon session, which is under the auspices of the Protective Devices Committee; these papers are *Reactors in Hydroelectric Stations*, by J. A. Johnson and *Protection of Transformer Neutrals Against Destructive Transient Disturbances*, by Max H. Collbohm.

EVENING

The evening will be devoted to a social function which is being arranged by the Entertainment Committee, the details of which will be published in the February PROCEEDINGS.

Thursday, February 15

MORNING SESSION

The morning session will be held under the auspices of the Electrophysics Committee, and three papers will be presented as follows: *Corona and Rectification in Hydrogen* by J. W. Davis and

Digitized by Google

C. S. Breese; *The Electric Strength of Air-VII* by J. B. Whitehead and W. S. Brown; *Oscillating Current Circuits by the Method of Generalized Angular Velocities* by V. Bush.

AFTERNOON

Thursday afternoon will be devoted to inspection trips which are being planned by Technical Excursion Committee, and there will also be a number of committee meetings which will be announced later, and the regular monthly meeting of the Board of Directors.

EVENING

Thursday evening will be devoted to a lecture by Prof. R. A. Millikan on the subject of *Modern Physics*.

The importance of the complete cooperation and mutual understanding of the engineer and physicist has been well emphasized in the past few years. Rapid advance, and the fact that the results of physical research are usually expressed in higher mathematics, and in the proceedings of physical and philosophical societies, seldom read by engineers, have made it difficult for them to keep informed. Hoping to further the cooperation between physicists and engineers, the Electrophysics Committee of the American Institute of Electrical Engineers, has been very anxious to have placed before them in simple language, not involved in higher mathematics, some of the modern conceptions in Physics. Prof. R. A. Millikan, President of the Physical Society, has kindly consented to do this.

The Electrophysics Committee of the American Institute of Electrical Engineers has been assisted in making arrangements, by the Committee on Technical Physics of the American Physical Society.

Prof. Millikan is President of the American Physical Society, Professor of Physics at the University of Chicago, and author of a number of text books on physics. He was awarded the Comstock Prize for research in electricity by the National Academy of Science, 1913; he has done some very important research work and is probably best known for his work on the isolation and measurement of the electron.

Friday, February 16

MORNING SESSION

The morning session will be under the auspices of the Industrial and Domestic Power Committee which will present two papers dealing with the control of direct-current motors. These papers are *Industrial Controllers with Particular Reference to the Control of D-C. Motors* by H. D. James; and *Analysis of Starting Characteristics of D-C. Motors* by K. L. Hansen.

AFTERNOON

The final session of the convention will be held Friday afternoon and it is also under the auspices of the Industrial and Domestic Power Committee, the general subject being control of alternating-current motors. The two papers for this session are entitled *Transient Conditions in Asynchronous Induction Machines and Their Relation to Control* by R. E. Hellmund; and *Performance of Polyphase Induction Motors Under Unbalanced Secondary Conditions* by A. A. Gazda.

NOMINATIONS FOR INSTITUTE OFFICERS FOR 1917-18

As provided in Section 20 of the Institute by-laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1917, by the petition or by the separate endorsement in writing, of not less than fifty members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1917. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available.

The officers to be elected are: a President and Treasurer, for the term of

Digitized by Google

one year each, three Vice-Presidents for the term of one year each, and four Managers, of whom the junior one shall serve for three years and the senior three for four years each.

For the information of members, the full text of Section 20 of the by-laws, governing the proposal of candidates for nomination, is printed below:

Sec. 20. In addition to the names of the incumbents of office, the Secretary shall publish on 'the form showing offices to be filled at the ensuing annual election in May,' provided for in Article VI of the Constitution, the names as candidates for nomination, of such members of the Institute as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than fifty members, received by the Secretary of the Institute in writing by January 25 of each year.

FUTURE INSTITUTE MEETINGS

Chicago, Ill., March 9, 1917. This meeting will be held under the auspices of the Chicago Section and the Committee on Protective Devices. The general subject will be: Recent Changes in Overload Relay Practise. Two papers will be presented, one by Philip Torchio and the other by R. F. Schuchardt, each telling of recent changes and developments in relay practise. The exact titles of these papers will be announced later.

The places and dates for other Institute meetings in 1917, so far as authorized by the Board of Directors, are as follows:

Schenectady, N. Y., April 13, 1917.

New York, May 18, 1917, Annual Meeting.

The Annual Convention will be held during the week beginning June 25, 1917.

The Pacific Coast Convention of 1917 will be held in Los Angeles, Cal., at a date to be announced later.

FUTURE SECTION MEETINGS

Chicago.—January 22, 1917. Subject: Electrochemical Processes.

February 26, 1917. Subject: The Making of Rates After Valuation.

Detroit-Ann Arbor.—January 14, 1917, Ann Arbor. Prof. Franklin will give a lecture on "Mechanical Analogies in Electricity and Magnetism".

January 28, Detroit.

Pittsfield.—January 4, 1917. Paper: "Aluminum and Its Alloys" by E. Blough.

January 18, 1917. Paper: "Electric Ship Propulsion" by W. L. R. Emmet.

Schenectady.—January 4, 1917. Subject; "X-Rays and Their Uses". Speakers: Dr. W. P. Darcy and Dr. A. W. Hull.

January 19, 1917. Speaker: Prof. C. F. Scott.

Spokane.—January 19, 1917. Subject: Municipal Engineering. February 16, 1917. Subject: Transmission and Distribution.

A. I. E. E. DIRECTORS' MEETING BOSTON, MASS., DECEMBER 8, 1916

The regular monthly meeting of the Board of Directors was held at the Massachusetts Institute of Technology, Cambridge, Mass., on Friday, December 8, 1916, at 11:00 a.m.

There was present: President H. W. Buck, New York; Past-President Paul M. Lincoln, Pittsburgh, Pa.; Vice-Presidents C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., B. A. Behrend, Boston, Mass., L. T. Robinson, Schenectady, N. Y.; Managers A. S. McAllister, New York, John B. Taylor, Schenectady, N. Y., Charles Robbins, Pittsburgh, Pa., N. A. Carle, Newark, N. J.; and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $9,959.08, was ratified.

The report of the Board of Examiners at its meeting held on November 28 was read, and the actions taken at that meeting were approved.

Announcement was made of the expiration, on the fourth Thursday of

Digitized by Google

January 1917, of the term of Mr. H. H. Barnes, Jr., as one of the Institute's three representatives upon the Board of Trustees of the United Engineering Society. Mr. Calvert Townley was appointed by the Board of Directors to succeed Mr. Barnes for the three year term ending on the fourth Thursday in January 1920.

Dr. Samuel Sheldon, whose term as a representative of the Institute upon the Library Board of the United Engineering Society expires on December 31, 1916, was re-appointed for the term of four years, ending December 31, 1920.

The Secretary announced that in accordance with Section 87 of the Institute by-laws, President Buck would become a member of the John-Fritz Medal Board of Award on the third Friday of January 1917, to succeed Mr. Ralph D. Mershon whose term will expire upon that date.

It was voted to hold the next meeting of the Board of Directors in Pittsburgh, Pa., upon the date of the Pittsburgh Institute meeting, January 12, 1917.

ANNUAL MEETING OF SOCIETY OF AUTOMOBILE ENGINEERS

The Society of Automobile Engineers will hold its Annual Meeting on January 11, 1917. In the morning the Business Session will be held. The Professional Session to which all members of the A. I. E. E. are cordially invited will be held in the Auditorium of the Engineering Societies building at 1:00 o'clock. The following papers will be presented. Some Problems in Airplane Construction—Capt. V. E. Clark; The Ultimate Type of Tractor Engine—H. L. Horning; Dynamic Balance of Rotating Parts and Dynamic Balancing Machines—F. Hymans; Dynamics of the Automobile—N. W. Akinoff; Some Essential Features of High-Speed Engines—A. F. Milbrath; Heat Balance Tests of Automobile Engines—W. T. Feshleigh and W. E. Lay; Aerial Navigation Over Water—Elmer A. Sperry.

A. I. E. E. MEETING IN BOSTON DECEMBER 9, 1916

The 327th meeting of the American Institute of Electrical Engineers was held on December 9, 1916 in the Central Lecture Hall of the Massachusetts Institute of Technology, Cambridge, under the auspices of the Boston Section and the Protective Devices Committee. Two sessions were held, the technical session at 3 p. m. and the evening session devoted to the presentation of the John Fritz Medal at 8.30 p. m.

In addition to the regular sessions, there were a number of committee meetings and social functions, as follows:

Standards Committee meeting at 9 a. m., Finance Committee meeting at 10.30 a. m. and Board of Directors meeting at 11 a. m.

Several inspection trips to central stations and manufacturing plants were arranged for between 9 a. m. and 1 p. m. and proved of interest to a considerable number. At 1 p. m. the Board of Directors was given a luncheon at the Harvard Club as guests of Professor C. A. Adams and Mr. B. A. Behrend. An informal dinner at the Riverbank Court was held at 6.30 p. m. and was attended by about two hundred members of the A. I. E. E. and their guests.

President Harold W. Buck calling the afternoon meeting to order, briefly reviewed the serious situation that electrical engineers of twenty years ago faced, when called upon to install devices capable of successfully opening high-tension circuits. He pointed out how this situation was cleared up by the introduction of the oil switch and how that in turn seems to be approaching certain capacity limits. President Buck introduced Mr. S. Q. Hayes of the Westinghouse Electric and Manufacturing Co., who presented his paper, entitled *Rupturing Capacities of Oil Circuit Breakers.*

Mr. E. M. Hewlett of the General Electric Company then presented his

Digitized by Google

paper, entitled *Rating of Oil Circuit Breakers.*

Those who participated in the discussion were Messrs. Chester Lichtenberg, N. L. Pollard, George A. Burnham, John L. Harper, John B. Taylor, K. C. Randall, L. E. Imlay, C. A. Adams, E. N. Hewlett, S. Q. Hayes, H. R. Summerhayes, P. M. Lincoln, L. W. Chubb and H. W. Buck.

PRESENTATION OF THE JOHN FRITZ MEDAL

The evening session of the Boston meeting of the Institute, held December 8, was assigned to the John Fritz Medal Board of Award, in accordance with a request received from that board that arrangements be made for the presentation of the John Fritz Medal to Dr. Elihu Thomson, Past President of the American Institute of Electrical Engineers, at a suitable meeting of the Institute.

With the central lecture hall of the Massachusetts Institute of Technology at Cambridge, comfortably filled with a distinguished gathering of engineers, scientists and other guests and with most of the members of the Board of Award occupying the platform, the meeting was called to order at 8.30 p. m. by Professor Albert Sauveur, Chairman of the John Fritz Medal Board of Award, who spoke as follows:

"It is my pleasant duty to call this meeting to order, in order that we may proceed with the ceremonies of presentation of the John Fritz Medal to Professor Elihu Thomson, who was nominated to be the medalist at the stated meeting in January, 1915, and elected at the following stated meeting in January, 1916, his name, according to requirements, having been before the Board for a period of one year.

"The first speaker of the evening will be Mr. John J. Carty, the Chairman of the Committee of Presentation of the Board of Award, who will tell us something of the history and significance of the John Fritz Medal."

Extracts from Address of John J. Carty

"My function in the ceremonies of this evening is to me a very pleasant one. It is to tell some things about the significance of the medal which is to be awarded.

"The John Fritz Medal was established by the professional associates and friends of John Fritz of Bethlehem, Penn., on August 21, 1902, his eightieth birthday, to perpetuate the memory of his great achievements in industrial progress. The medal is awarded for notable scientific or industrial achievement. As there is no restriction on account of nationality or sex, the recipient of this medal is distinguished as being selected out of all the inhabitants of the earth as being the most worthy to receive it.

"The medal may be awarded annually by a Board of sixteen, appointed or chosen in equal numbers from the membership of the four national societies the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers.

"The first impression from the artist's design was given to Mr. Fritz himself at a great dinner given in his honor at the Waldorf Hotel in New York in 1902. Those to receive the medal subsequently were Lord Kevlin, George Westinghouse, Alexander Graham Bell, Thomas Alva Edison, Charles T. Porter, Alfred Noble, Sir William Henry White, Robert Woolston Hunt, John Edson Sweet and James Douglas.

"And to-night, gentlemen, we are to add to this distinguished list of great men, for his achievements in electrical invention, in electrical engineering and industrial development and in scientific research, the name of another great man who is well known and beloved by us all, Elihu Thomson."

Chairman Sauveur next introduced Mr. E. W. Rice Jr. President of the General Electric Co., who spoke, in part, as follows:

Digitized by Google

FROM ADDRESS OF E. W. RICE, JR.

"The medal which was awarded in January 1916 to Dr. Elihu Thomson, and which is to be presented to-night, is for "Achievements in Electrical Inventions, in Electrical Engineering, in Industrial Development and in Scientific Research."

"It would be impossible in the brief time at our disposal to adequately describe the achievements of our medalist in these various fields. In the field of electrical inventions alone Prof. Thomson has been awarded something over 550 United States patents, and in other fields, notably mechanical work, about 150 patents. He has made contributions to the world's scientific and technical literature, set forth in several hundred articles describing not only his own discoveries and inventions but making remarkably interesting contributions to scientific speculation and thought.

"Prof. Thomson's electrical work began about 37 years ago with the invention of the three-coil arc dynamo, which, with its automatic regulator, and other novel features, formed the basis of the successful lighting system put out by the Thomson-Houston Company beginning in 1880. This machine was remarkable for its extreme simplicity, ruggedness, flexibility and general efficiency.

"You will be interested to learn that the original application for a patent for this three-coil machine showed that it could also be used to produce alternating currents. This alternating-current feature was but one instance of many where Prof. Thomson's ideas were years in advance of the world's readiness for their reception.

"The next important electrical invention was the utilization of a magnetic field to mechanically propel an electric arc. This idea took many forms and was first applied some time in 1881 in connection with a lightning arrester for his arc light system. His first lightning arrester took the form now well known as the horn lightning arrester, the gap between the horns being surrounded by the poles of a magnet. The first model of this lightning arrester was immediately put into commercial use and was manufactured without alteration for many years.

"This important principle was immediately extended to the construction of switches in which the magnetic field was used to interrupt the arc formed upon breaking a circuit. All these devices are known as magnetic-blowout devices and are used on a very extensive scale at the present time; notable applications being found in the controllers for electric street cars, on electric trains for elevated roads and on large electric locomotives.

"Prof. Thomson was one of the earliest workers in the field of alternating currents. As I have stated, his first three-coil dynamo was also intended to be used as an alternator. The modern transformer system with transmission at high potential and reduction of the potential in the secondaries of the Transformers was worked upon at the Franklin Institute in Philadelphia in 1879, and in February of that year he ran two transformers by an alternating dynamo with the fine wire primaries connected in parallel to the dynamo line and the secondaries doing the local work.

"A patent granted in 1883 for a reactive coil points out very clearly the distinction between a resistance and a reactance, and sets forth the practical value of the ractive coil in regulating an controlling alternating-current circuits.

"While, as stated, Prof. Thomson had at a very early date confidence in the commercial value of alternating current, he objected to its commercial exploitation because he believed that no insulation could be devised which would make it impossible for the high-pressure alternating current to occasionally come into contact with the low-pressure circuits with fatal results to the unsuspecting users. It was not until he conceived the idea of grounding the second-

Digitized by Google

ary circuit which eliminated this danger, that he was willing to push the development of alternating current for commercial purposes. This idea of grounding the secondary circuit, in order to insure safety, is first disclosed in one of his patents granted in 1885.

"The year 1886 is notable for the invention of the art and process of electric welding which has already gone into very extensive use and which perhaps constitutes one of his most notable achievements, as by this invention he has contributed an entirely new art to the world.

"In 1887, 1888 and 1889 Prof. Thomson first proposed the method of using oil for insulating and cooling transformers; a method universally used at the present time; and invented the constant current transformer.

"The alternating-current induction regulator, in which a movable secondary or primary is used, to vary the mutual induction and thereby control the current and voltage in an alternating-current circuit, was devised in 1888.

"About this time Prof. Thomson made a large number of brilliant discoveries in connection with alternating-current repulsion phenomena, and patented the first alternating-current single-phase repulsion motor, the basis of the existing single-phase motor.

He rapidly devised instruments for the accurate measurement of alternating current and other apparatus needed in its regulation and distribution.

"He also made the first very high-frequency dynamo. This was constructed in 1890 to give 4000 cycles a frequency from 30 to 40 times higher than that hitherto produced in a dynamo electric machine. Shortly after the introduction of this high-frequency dynamo he originated the method of producing a high-frequency alternating current from a direct-current arc by shunting the arc with inductance and capacity. About this time also he produced his high-frequency transformer, made a series of brilliant investigations and developed apparatus of extreme scientific interest, which form the basis of wireless telephone and telegraph work.

"In this same decade, 1885 to 1895, we find Prof. Thomson busily engaged with electric meters, and as an outcome various meters known by his name were designed, of which over 4,000,000 have been sold and are now in operation. He also invented the electrical switch, operated from a distance, which forms the basis of the switching devices used on electric elevators, trolley cars, electric locomotives and electric trains on elevated and suburban roads, the essential features of the so-called multiple-unit system.

"In addition to these electrical inventions and contributions to electrical engineering, Prof. Thomson's active mind has found time to make valuable contributions in other lines. Among the earliest patents is a joint patent with Prof. Houston on a centrifugal creamer, filed in 1877 and issued in 1881.

"In this connection may be mentioned the electric air drill. In 1894 he devised a muffler for automobiles, a form of muffler which embodies a silencing principle which is remarkable for its effectiveness, and interesting because it employs the method of dividing up an impulse and lagging certain parts of it behind others so as to prevent an explosive shock and spread the impulse over a considerable time. He also devised numerous gas and oil engines, and developed a method of manufacturing fused quartz by electrical means, which gives every evidence of being the best yet devised.

"It may not perhaps be generally known that our medalist is as much at home in the science of optics, in the practical application of its laws and in the design and use of apparatus, as he is with those of electrical science. If he had not chosen electrical engineering as his profession, but that of optics, he probably would have made a reputation

Digitized by Google

in that field comparable with that which he has made in electricity.

"He is equally at home in the science and practise of acoustics. Back in 1875 he constructed a pipe organ with several banks of pipes and with electropneumatic key action; many of the features of which have been adopted in the industry.

"Prof. Thomson's scientific researches have been largely associated with his inventions, as his inventions are not those of the happy-go-lucky kind but are the result of careful and thorough research.

"One of the earliest wireless experiments, of which I have knowledge, was made by Profs. Thomson and Houston at the old High School in Philadelphia, in the Winter of 1879-80.

"His first important research covered a study into the nature of and the electrical laws governing the operation of the electric arc. The results of this investigation were published in the Franklin Institute Journal in 1879.

"In February, 1896, was published the results of a careful research conducted several years previously as to the dielectric strength of insulating oils under alternating-current potentials; he points out for the first time the interesting and important fact that with high frequencies, the insulating power of oil always is, as measured by the striking distance in air relative to that in the oil, far in excess of the insulating power for low frequencies. In this research attention is called for the first time to the extremely deleterious effect upon the insulating power of oil of an exceedingly minute quantity of moisture.

"We hope that this sketch of Prof. Thomson's work, brief and imperfect as it is, will serve to illustrate the extent and variety of his knowledge and the range of his mental activities, and the ingenuity and great practical value of his work.

"As a close observer of Prof. Thomson's activities for over thirty-six years I may be able to say something of interest as to his method of work. A skilled workman, he is always able to himself do the work which he asks others to perform. He prefers to make his own drawings, freehand sketches, to which he adds dimensions and a short written description. He selects his own materials, supervises the work, quickly makes such modifications as may be needed during its progress and stands constantly ready to give just the advice necessary to help over difficult places and turn failure into success. His inventions are the result of profound and accurate knowledge. In fact, Prof. Thomson perhaps more than any other inventor since the days of Henry or Faraday, combines in his person profound and accurate scientific knowledge with extraordinary technical skill.

"It is difficult to restrain enthusiasm for one who has given the world so much, who has been and still continues to be such an inspiring example to all workers in science and industry."

Dr. Richard C. Maclaurin, President of the Massachusetts Institute of Technology was introduced as the next speaker.

Extracts from Address by Richard C. Maclaurin

"It is a pleasure to take part in this tribute of respect to Professor Thomson not merely because of my association with him in the management of the affairs of the M. I. T., and the high personal regard that association with such a man entails, but because I realize that he is an educational force of great potency and that it is in the very highest interests of education that his merits should be widely appreciated and at least occasionally acclaimed.

"Much nonsense has been spoken and written about the merits of national expositions and amongst the statements that might fairly be placed in this class is one to the effect that it was the Paris Exposition of 1878 that *made* Thomson an inventor. It has been forces within Professor Thomson far more than forces outside that have contributed to his

Digitized by Google

great success. He was twenty-five years of age at the time of the Paris Exposition and had already received a sound scientific training and earned distinction in his chosen field. Doubtless his visit to the Exposition stimulated his imagination and gave an incentive to his work, but it can hardly have made him an inventor. Be that as it may, it was not long thereafter that he became a marked man, through his notable contributions to science and its industrial applications.

"It is certain that no mere enumeration of invention suffices as a measure of the man. It does not even suggest the whole story on its strictly scientific side. Many men come to an end of their rope when they have made a specific invention. It is only a few who can correlate a series of inventions into an organized machine that will be effective and economical, and amongst such men Thomson is transcendent. Apart from this, however, as with all scientists of similar quality, the man is far more than the inventor. It would be an impertinence on my part to give you the full measure of the man, but I will touch on one or two aspects of his personality that are indicative of qualities making powerfully for his own success and contributing largely to his stimulating influence on others.

"Much has happened in recent years to awaken the world to an appreciation of the fact that industrial improvement and national well-being depend very largely on the progress of science. Consequently, more attention is being given now than ever before to the problems of the schools of applied science. One of the greatest of the problems that confront these schools is the problem of finding adequate means of encouraging the spirit of scientific research. We must, of course, do this through our teachers and the fundamental problem is to find and to attract men who combine two rare qualities; first the power of extending the boundaries of knowledge; and second, the power of stimulating others to equally effective endeavor. Thomson, had he continued in the schools, would have made the ideal teacher in this respect. Throughout his life he has not only done great things himself but shown an intense desire to help all who are struggling earnestly with scientific problems. He has proved an inspiration to an ever widening circle of engineers and others who have entrusted him with their secrets and sought his help in overcoming their difficulties.

"In these days of increasing specialization men's vision is often narrower rather than wider as they advance in years. Thomson so far as his interests are concerned has taken the whole field of scientific development for his parish, not, of course, that he cultivated the whole field; but he has an intelligent interest in and an extraordinarily wide knowledge of what is going on in almost every portion of that field. It has sometimes seemed to me that not the least significant fact in regard to Professor Thomson's work is the fact, known to those who have had the pleasure of seeing him in his home, that his laboratory is built right into the home and is an integral part of it. Probably thoughts on scientific problems are never wholly absent from his mind, although he may be consciously thinking of quite other matters."

Presentation of Medal by Charles Warren Hunt.

"It has been my good fortune to have been a member of the John Fritz Medal Board continuously since its inception fourteen years ago. And at this moment the selfish thought comes to my mind that no one else knows as well as I do just how interesting and delightful has been that long association with the representatives of all branches of the engineering profession, appointed for the purpose of singling out each year a man of practical science to receive this special honor.

"While the task of this Board is, as I said, a delightful one, it is, nevertheless, not an easy one. There are many men

Digitized by Google

in the engineering profession who deserve to be signally honored. And it has seemed to me, during the deliberations of this Board, that in one sense it is too bad that there are not more medals to award.

"As has been said in other words this evening, since the presentation of the original medal to John Fritz on the occasion of his eightieth birthday I believe every one will agree that each succeeding award has strengthened the remarkable group of men whose achievements have added material to the welfare, safety, convenience and happiness of their fellow-man. The award which I am about to have the honor of making officially is certainly no exception to that rule.

"Professor Thomson, I now have the honor of presenting to you, sir, on behalf of your brother engineers, as represented by the Board of Award, the John Fritz Medal for 1916.

RESPONSE BY ELIHU THOMSON.

"Words fail me when I try to express my deep sense of appreciation of the honor done me on this occasion.

"As an award the John Fritz medal is itself exceptional, being accorded by a body made up of leaders in four engineering professions. For that reason it is more than usually distinctive.

"If in the past forty years of work it has fallen to my lot to contribute in some degree to the advance of science and engineering, that fact alone is a great satisfaction. In the doing of a task, no matter how great or how small there is always a certain joy—the joy of accomplishment which is the immediate recompense for the effort and labor involved.

It is my desire too, that it be not forgotten that others have shared in the work, perhaps by collaboration, by encouragement; often in helping to establish suitable conditions or environment. These should properly share in the honors.

"It need not be denied that at times there have been heavy burdens, discouragements and obstacles, but these should only stimulate to greater effort. Looking back, it is the nature of man to treasure in memory the best—the happenings that have brought pleasure and satisfaction. Were it otherwise the outlook would be bad for progress or even for survival of the race itself. Above all must the investigator, the pioneer, be possessed of an unquenchable spirit of optimism: The unknown or unaccomplished must be to him a sort of challenge.

"It may be interesting to mention here that I was present in New York on the occasion of the establishment of the John Fritz Medal, and then met the staunch veteran himself in whose honor it was created. I heard him tell of his early struggles, and experiences. His, indeed, was an indomitable spirit and ardor that cannot fail to succeed. The occasion was memorable. Seated as a listener it was furthest from my thought that the testimonial would ever come to me, as it now has.

"I thank the Board of Award most sincerely for this beautiful token of confidence and appreciation bestowed, and assure the members that I esteem it most highly.

"In the years past I have simply worked on the problems before me—things needed to be done or worthy to be done—I verily believe I could not have helped it if I had tried. Difficulties often arose, but I certainly enjoyed to the full the satisfactions and rejoiced if the general progress was in any degree assisted.

"Beginning active life as a teacher, not the least part of the satisfaction has been to assist other workers freely by advice or suggestions based on knowledge gained.

"In conclusion permit me to add that I am deeply touched by the presence on an occasion so special to myself of so many friends; to each and all of whom I desire to convey my grateful acknowledgments. To the speakers who have enlightened you and embarrassed me I owe a special debt.

Digitized by Google

great success. He was twenty-five years of age at the time of the Paris Exposition and had already received a sound scientific training and earned distinction in his chosen field. Doubtless his visit to the Exposition stimulated his imagination and gave an incentive to his work, but it can hardly have made him an inventor. Be that as it may, it was not long thereafter that he became a marked man, through his notable contributions to science and its industrial applications.

"It is certain that no mere enumeration of invention suffices as a measure of the man. It does not even suggest the whole story on its strictly scientific side. Many men come to an end of their rope when they have made a specific invention. It is only a few who can correlate a series of inventions into an organized machine that will be effective and economical, and amongst such men Thomson is transcendent. Apart from this, however, as with all scientists of similar quality, the man is far more than the inventor. It would be an impertinence on my part to give you the full measure of the man, but I will touch on one or two aspects of his personality that are indicative of qualities making powerfully for his own success and contributing largely to his stimulating influence on others.

"Much has happened in recent years to awaken the world to an appreciation of the fact that industrial improvement and national well-being depend very largely on the progress of science. Consequently, more attention is being given now than ever before to the problems of the schools of applied science. One of the greatest of the problems that confront these schools is the problem of finding adequate means of encouraging the spirit of scientific research. We must, of course, do this through our teachers and the fundamental problem is to find and to attract men who combine two rare qualities; first the power of extending the boundaries of knowledge; and second, the power of stimulating others to equally effective endeavor. Thomson, had he continued in the schools, would have made the ideal teacher in this respect. Throughout his life he has not only done great things himself but shown an intense desire to help all who are struggling earnestly with scientific problems. He has proved an inspiration to an ever widening circle of engineers and others who have entrusted him with their secrets and sought his help in overcoming their difficulties.

"In these days of increasing specialization men's vision is often narrower rather than wider as they advance in years. Thomson so far as his interests are concerned has taken the whole field of scientific development for his parish, not, of course, that he cultivated the whole field; but he has an intelligent interest in and an extraordinarily wide knowledge of what is going on in almost every portion of that field. It has sometimes seemed to me that not the least significant fact in regard to Professor Thomson's work is the fact, known to those who have had the pleasure of seeing him in his home, that his laboratory is built right into the home and is an integral part of it. Probably thoughts on scientific problems are never wholly absent from his mind, although he may be consciously thinking of quite other matters."

Presentation of Medal by Charles Warren Hunt.

"It has been my good fortune to have been a member of the John Fritz Medal Board continuously since its inception fourteen years ago. And at this moment the selfish thought comes to my mind that no one else knows as well as I do just how interesting and delightful has been that long association with the representatives of all branches of the engineering profession, appointed for the purpose of singling out each year a man of practical science to receive this special honor.

"While the task of this Board is, as I said, a delightful one, it is, nevertheless, not an easy one. There are many men

Digitized by Google

in the engineering profession who deserve to be signally honored. And it has seemed to me, during the deliberations of this Board, that in one sense it is too bad that there are not more medals to award.

"As has been said in other words this evening, since the presentation of the original medal to John Fritz on the occasion of his eightieth birthday I believe every one will agree that each succeeding award has strengthened the remarkable group of men whose achievements have added material to the welfare, safety, convenience and happiness of their fellow-man. The award which I am about to have the honor of making officially is certainly no exception to that rule.

"Professor Thomson, I now have the honor of presenting to you, sir, on behalf of your brother engineers, as represented by the Board of Award, the John Fritz Medal for 1916.

RESPONSE BY ELIHU THOMSON.

"Words fail me when I try to express my deep sense of appreciation of the honor done me on this occasion.

"As an award the John Fritz medal is itself exceptional, being accorded by a body made up of leaders in four engineering professions. For that reason it is more than usually distinctive.

"If in the past forty years of work it has fallen to my lot to contribute in some degree to the advance of science and engineering, that fact alone is a great satisfaction. In the doing of a task, no matter how great or how small there is always a certain joy—the joy of accomplishment which is the immediate recompense for the effort and labor involved.

It is my desire too, that it be not forgotten that others have shared in the work, perhaps by collaboration, by encouragement; often in helping to establish suitable conditions or environment. These should properly share in the honors.

"It need not be denied that at times there have been heavy burdens, discouragements and obstacles, but these should only stimulate to greater effort. Looking back, it is the nature of man to treasure in memory the best—the happenings that have brought pleasure and satisfaction. Were it otherwise the outlook would be bad for progress or even for survival of the race itself. Above all must the investigator, the pioneer, be possessed of an unquenchable spirit of optimism: The unknown or unaccomplished must be to him a sort of challenge.

"It may be interesting to mention here that I was present in New York on the occasion of the establishment of the John Fritz Medal, and then met the staunch veteran himself in whose honor it was created. I heard him tell of his early struggles, and experiences. His, indeed, was an indomitable spirit and ardor that cannot fail to succeed. The occasion was memorable. Seated as a listener it was furthest from my thought that the testimonial would ever come to me, as it now has.

"I thank the Board of Award most sincerely for this beautiful token of confidence and appreciation bestowed, and assure the members that I esteem it most highly.

"In the years past I have simply worked on the problems before me—things needed to be done or worthy to be done—I verily believe I could not have helped it if I had tried. Difficulties often arose, but I certainly enjoyed to the full the satisfactions and rejoiced if the general progress was in any degree assisted.

"Beginning active life as a teacher, not the least part of the satisfaction has been to assist other workers freely by advice or suggestions based on knowledge gained.

"In conclusion permit me to add that I am deeply touched by the presence on an occasion so special to myself of so many friends; to each and all of whom I desire to convey my grateful acknowledgments. To the speakers who have enlightened you and embarrassed me I owe a special debt.

Digitized by Google

"A final word to the younger men who must be entrusted with the future. If to them the way may at times seem long, the obstacles many, the self denial and effort extreme, I would say,—enthusiasm, the habit of constant thought, never shrinking from seemingly hard tasks, honesty of purpose and the realization that obstacles are often only stepping stones in disguise, will go far to insure coveted success."

TOPOGRAPHICAL MAP OF UNITED STATES

For some time there has been a movement to expedite the completion by the United States Geological Survey of a topographical map of the United States, and with the object of assisting in this movement, the Board of Directors adopted the following resolution at a meeting held November 10, 1916:

WHEREAS, a complete topographical map of the United States would be of inestimable value to Engineers in connection with the development of Hydroelectric, Irrigation, Highway, Railway, Mining and other engineering enterprises.

RESOLVED, that this Board hereby extends its earnest support to the movement to expedite the completion by the U. S. Geological Survey of the topographical map of the United States, and urges the interested members of this Institute to use their influence with their Congressmen to the end that a larger appropriation be made for the topographical work of the U. S. Geological Survey.

RESEARCH FELLOWSHIPS, UNIVERSITY OF ILLINOIS

The University of Illinois maintains fourteen Engineering Experiment Station Research Fellowships and one other such fellowship has been established under the patronage of the Illinois Gas Association. These fellowships, annual stipend $500.00 each, are open to graduates of approved American and foreign universities and technical schools. Appointments are made for two consecutive years.

Nominations to these fellowships, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the 1st of February.

PAST SECTION MEETINGS

Boston.—November 14, 1916. Address by Mr Leonard L. Howard on "Mica, Its Sources and Manufactured Product". Attendance 90.

Chicago.—October 25, 1916, Fullerton Hall. Address by Dr. C. P. Steinmetz on "The Effect of the European War on American Industries". Attendance 500.

Cleveland.—November 20, 1916, Hotel Statler. Paper: "The Lighting of the Home" by H. T. Spaulding. Joint meeting with Pittsburgh Section of Illuminating Engineering Society. Attendance 104.

Denver—November 18, 1916, Denver Athletic Club. Paper: "Street Railway Fallacies and Facts" by H. C. Kendall. Paper was illustrated by lantern slides. Attendance 32.

Detroit-Ann Arbor.—October 13, 1916, Detroit Engineering Society. Paper: "Electricity in the Baking of Protective Coatings" by C. F. Hirshfeld. Attendance 75.

November 10, 1916, Detroit Engineering Society. Paper: "Telephone Rates" by G. M. Welch. Attendance 45.

December 8, 1916, Ann Arbor. Paper: "Submarine Boats" by H. C. Sadler. Attendance 93.

Indianapolis-Lafayette. — November 9, 1916, Indianapolis. Paper: "Commutation of D-C. Machines with Interpoles," by Alfred Still. Attendance 36.

Election of officers as follows; chairman, J. L. Wayne, vice-chairman, C. F. Harding; secretary-treasurer, C. A. Cora; executive committee, Gordon E. Varney and A. N. Topping.

Ithaca.—November 17, 1916, Franklin Hall, Cornell University. Paper: "Large Single-Phase Loads from Three-Phase Stations" by E. F. Alexanderson. Attendance 67.

Kansas City.—November 11, 1916, Fort Leavenworth. Inspection of Federal Prison at Leavenworth, including the new addition and power plant.

Digitized by Google

Joint meeting with Engineers Club of Kansas City. Attendance 61.

December 11, 1916, Y. M. C. A. Paper: "The Electrical System of a Steam Railroad Terminal" by A. A. Thompson. Election of officers as follows: chairman, A. A. Thompson; secretary-treasurer, G. O. Brown. Attendance 26.

Lynn.—October 25, 1916. Burdett Hall. Adress by Mr. Farley Osgood on "The Human Side of Engineering". Attendance 250.

November 4th, 1916, Burdett Hall, Illustrated address by Lieutenant Colonel J. A. Shipton on "A Trip to the Argentine Republic". Attendance 400.

November 15, 1916, General Electric Hall. Symposium on "The Plattsburg Experience" presented by all members who attended Plattsburg Camp. A large number of pictures were shown and explained. Attendance 400.

November 22, 1917, General Electric Hall. Address by Prof. W. I. Slichter on "Education for a Career in Electrical Engineering". Attendance 250.

December 6, 1916, Burdett Hall. Lecture by Mr. Frank W. Skinner on "The Great War, and its Mechanical Equipment". Attendance 400.

Madison.—November 28, 1916, Engineering Building, University of Wisconsin. Paper: "Inductive Interference" by George H. Gray. Attendance 50.

Minnesota.—November 27, 1916, University of Minnesota, Minneapolis. Paper; "Electrification of Steam Railroads" by W. T. Whalen. The paper was illustrated by three reels of moving pictures. Attendance 200.

Panama.—October 25, 1916, Ancon Clubhouse. Subject Military Engineering. Illustrated address by Major C. O. Sherill on "Reconnaissance, Fortifications and Trench Warfare". Col. J. J. Morrow gave an outline of the Army Engineer Reserve. Attendance 285.

November 22, 1916, Ancon, C. Z. Subject: Military Engineering. Illustrated address by Major W. H. Rose on "Mines, Obstacles, Demolitions, Searchlights, Railroads and Armored Trains". Attendance. 270

Philadelphia.—October 18, 1916. Franklin Institute. Paper: "Scientific Research in Relation to the Industries" by Charles P. Steinmetz. Joint meeting with Franklin Institute. Attendance 300.

Pittsfield.—November 9, 1916, Wendell Hotel. Illustrated address by Major E. P. O'Hern on "Modern Field and Sea Coast Guns and Ammunition". Attendance 165.

Portland.—November 14, 1916, Y. M. C. A. Auditorium. Paper; "General Principles of Wireless Telegraphy and Telephony" by Walter Haynes. Joint Meeting with N. E. L. A. Attendance 70.

December 5, 1916, Y. M. C. A. Auditorium. Paper: "Design of Outside Telephone Plants" by W. E. Montrose. Joint meeting with local section of N. E. L. A. Attendance 30.

San Francisco—November 24, 1916, Engineers Club. Papers: (1) "A Study of the Ceramics of Insulators" by Harris J. Ryan; (2) "Progress Report on the Study by California Power Companies of Insulator Deterioration" by J. C. Clark; (3) "Investigation of Suspension Insulator Deterioration by California Power Companies" by J. E. Woodbridge and J. P. Jollyman. Attendance 102.

Schenectady.—November 17, 1916, Edison Club Hall. Fundamental Experiments on Electron Theory by Professor Charles T. Knipp. Attendance 370.

December 1, 1916, Edison Club Hall. Illustrated address by Mr. D. B. Rushmore on "Atmospheric Nitrogen and Its Uses". Attendance 300.

Seattle.—November 21, 1916, Lodge Room, Elks Club. Address by Mr. W. T. Whalen on "The Electrification of Steam Railroads". Address was illustrated with three reels of moving pictures. Election of officers as fol-

Digitized by Google

lows: chairman, C. E. Magnusson; secretary, C. F. Terrell. Attendance 170.

Spokane.—November 10, 1916, Chamber of Commerce Assembly Room Address by Mr. W. T. Whalen on "Electrification of Steam Railroads", illustrated by moving picture film. Attendance 100.

November 24, 1916, Telephone Company Building. Paper: "A Field Investigation of Inductive Interference in Telephone Circuits Arising form Parallelism with a 55,000-Volt Power Circuit" by R. W. Mastick. Attendance 59.

St. Louis.—November 15, 1916, Engineers Club. Paper: "Our Coast Defenses" by Captain Offnere Hope. Attendance 162.

December 6, 1916, Engineers Club. Election of officers as follows: chairman, A. McR. Harrelson; secretary, H. L. Hope. Attendance 16.

Toronto. November 24, 1916, Engineers Club. Illustrated address by Mr. A. O. Austin on "Important Factors that should be Considered in the Selection of an Insulator". Attendance 74.

PAST BRANCH MEETINGS

Alabama Polytechnic Institute.—Election of officers as follows: chairman, W. W. Hill; secretary, L. I. Davis; treasurer, W. T. Shinholser.

University of Arkansas.—November 20, 1916. Illustrated lecture by Dean Gladson on "The Pelton Water Wheel Company". Motion pictures of the Panama Canal Lock Control. Attendance 29.

December 4, 1916. Address by Professor W. B. Stelzner on "The History of Engineering". Motion pictures showing manufacture of insulators, generators, steam turbines, etc. Attendance 28.

University of California.—November 1, 1916. Address by Prof. F. E. Pernot on "Methods of Computing". Attendance 29.

November 15, 1916. Addresses as follows: "The Connections and Types of Frequency Meters, Power Factor Meters and Synchroscopes" by George Fleming; "High Frequency Oscillations from an Electric Arc" by H. K. Seung. Attendance 21.

November 29, 1916. Papers: "The Principles of the Phase Converter"; and "The Starting and Lighting System on the Automobile". Attendance 11.

Carnegie Institute of Technology.—November 14, 1916. Illustrated address on "A Trip Through the Schenectady Works of the General Electric Company" by J. H. Van Aernam. Attendance 80.

University of Colorado.—November 23, 1916. Address by Professor Evans on "History and Objects of the A. I. E. E." Attendance 42.

University of Idaho.—November 2, 1916. Moving picture of the Panama Canal with explanation by Professor L. J. Corbett. Moving pictures showing lumbering in some large camps and mills of Idaho, with explanatory remarks by Dean C. H. Shattuck. Attendance 38.

Iowa State College.—November 15, 1916. Illustrated address by Mr. C. I. Merrick on "The Chicago, Milwaukee and St. Paul Electrification in Montana", Attendance 43.

Kansas State Agricultural College.—November 2, 1916, Lecture Room, Denison Hall. Papers: (1) "Thury System of D-C. Transmission"; (2) "Current Events in Electrical Engineering"; "Operation on Norfolk and Western Railway". Attendance 129.

November 9, 1916, Assembly Room, Anderson Hall. Address by Mr. Shortridge Hardesty on "Engineering Ethics and the Bridge Engineer". Joint meeting with Engineering Association. Attendance 320.

November 16, 1916, Lecture Room Denison Hall. Papers: (1) "Theory and Construction of the Norfolk and Western Railway"; (2) "Motor Trucks Equipped for Construction Service"; (3) "Keokuk Project". Attendance 126.

University of Kansas.—November 22, 1916, Marvin Hall. Messrs. Smith,

Digitized by Google

Griffith and Spangler told of their experience on the Mexican border. Prof. Geo. C. Shaad gave a talk on the subjects offered in the engineering courses. Attendance 56.

Lafayette College.—November 18, 1916. Papers: (1) "Steel Towers for Transmission Lines" by H. C. Griffin; (2) "Corona Losses on Transmission Lines" by R. L. Dunlap. Attendance 17.

November 25, 1916. Papers; (1) "Methods of Rail Bond Testing" by W. S. Williams; (2) "Railway Electrolysis and Methods of Its Treatment" by C. T. Mack. Attendance 20.

Lehigh University.—December 14, 1916, Physics Lecture Room. Papers: (1) "The Work of the Valuation Engineer" by J. H. Bickley; (2) "The Electrification of a Paper Mill" by Jesse F. Wentz. Attendance 43.

University of Michigan.—November 15, 1916, New Engineering Building. Illustrated lecture by Prof. J. W. Langley on "Composition and Properties of Steel for Electrical Uses". Attendance 83.

University of Minnesota.—November 20, 1916, Engineering Auditorium. Address by Mr. W. L. Miller on "The Requirements of Public Service Utilities". Attendance 25.

University of Missouri.—November 27, 1916, Engineering Building. Paper: "The Engineer in War" by Major C. W. Castle. Attendance 63.

North Carolina College of Agricultural and Mechanical Arts. December 6, 1916. Election of officers as follows: chairman, F. E. Coxe; vice-chairman, E. P. Holmes; secretary-treasurer, F. J. Haight. Attendance 20.

Ohio State University.—November 24, 1916, Robinson Laboratory Papers: (1) "Aluminum Lightning Arresters" by L. W. Birch; (2) "Testing" by C. E. Mauk. Attendance 20.

December 8, 1916, Robinson Laboratory. Address by Prof. Hammond on "Employers' Liability Laws and the Workmen's Compensation Laws". Attendance 35.

December 14, 1916, Robinson Laboratory. Address by Mr. C. R. Underhill on "Electromagnets". Attendance 30.

Oregon Agricultural College.—November 23, 1916. Paper: "Practical Operation of Central Stations" by C. P. Osburne. Attendance 41.

Pennsylvania State College.—November 10, 1916, Club Room. Address by Prof. C. L. Kinsloe on "The A. I. E. E." Mr. Stephanson spoke on "The Armored Tractor 'Tanks' Used in the English Army". Attendance 47.

December 14, 1916, Engineering Club Room. Address by Mr. Mills on "Some Injurious Effects to the Human System due to High Voltage". Attendance 40.

Purdue University.—November 14, 1916, Electrical Building. Paper: "Flood Lighting" by H. F. Dart. Election of Mr. W. B. Wells as president to take the place of Mr. R. H. Townsend, who resigned. Attendance 42.

November 27, 1916, Lecture by Mr. M. Luckiesh on "Color". Attendance 200.

Rensselear Polytechnic Institute.—December 12, 1916, Sage Laboratory. Address by Mr. J. H. Steurer on "A Proposed Wireless Telegraph Station for the Rensselaer Polytechnic Institute". Attendance 51.

Syracuse University.—November 16, 1916. Address by Mr. M. T. Cappon on "Manufacture of Nitric Acid". Attendance 13.

November 23, 1916, Paper: "The Big Creek Hydroelectric Power Development of the Pacific Light & Power Co"., by H. E. Mason. Attendance 15.

December 7, 1916, Illustrated lecture by Mr. D. J. Burke on "Types of Magnetos". Attendance 11.

December 14, 1916. Illustrated lecture by Mr. D. J. Burke on "Types of Magnetos—Part II". Attendance 16.

Virginia Polytechnic Institute.—November 28, 1916, Science Hall. Address by Prof. L. S. Randolph on "Benefits Derived from being a Member of a

Digitized by Google

Large Engineering Society". Attendance 26.

December 7, 1916, Science Hall. Paper: "Electric Traction" by G. G. Coleman, R. S. Gray and J. L. Eley. Attendance 20.

University of Virginia.—November 22, 1916, Engineering Building. Papers: (1) "Chicago, Milwaukee and St. Paul Electrification" by J. K. Peebles, Jr.; (2) "The Sperry Searchlight" by Charles Henderson; (3) "A Modern Telephone Equipment" by W. S. Rodman. Attendance 12.

Worcester Polytechinc Institute.—November 17, 1916, Electrical Engineering Hall. Moving pictures of the Norfolk and Western, the Pennsylvania, The Boston and Maine, and the N. Y. N. H. & H. railroad electrification. Attendance 250.

December 15, 1916, Address by Mr. William J. Hammer on "Selenium and Its Scientific and Industrial Applications". Attendance 90.

Yale University.—November 21, 1916, 10 Hillhouse Avenue, New Haven. Address by Dr. William McClellan on "Problems of Public Utilities". Attendance 90.

PERSONAL

Mr. Charles F. Thompson, for several years associated with the railway and engineering departments of the General Electric Company, has resigned to take up commercial engineering with the Research Corporation, 63 Wall Street, New York City.

Mr. Lewis A. Shrewsbury, formerly with "Las Dos Estrellas" Mining Company of Mexico in now with the Braden Copper Company of Rancagua, Chile.

Mr. William C. Chappel has resigned his position as electrical engineer with Messrs. Siemens Bros. Dynamo Works, London, England and has been appointed Chief Assistant Engineer to the Government of Tasmania in the hydroelectric department, Hobart, Tasmania.

Mr. E. W. P. Smith who has been City Electrician, Cleveland, Ohio, for the past three years has resigned to accept the position of Consulting Engineer with the Elliot Electric Company, 322 Champlain Ave., Cleveland, Ohio. Mr. Smith is chairman of the Cleveland Section of the A. I. E. E., a member of the Chamber of Commerce, the Jovians, the Electrical League and the Cleveland Engineering Society.

Mr. Arthur H. Robbins has resigned his position as prevocational instructor in electricity in the Boston Public schools to accept a position as electrical engineer with the Electric Light and Power Company of Abington and Rockland, N. Abington, Mass. Mr. Robbins was connected with his present company from 1906 to 1914 as foreman of the meter department and during the two succeeding years was electrician in the plant of the National Fireworks Manufacturing Company.

RECOMMENDED FOR TRANSFER, NOVEMBER 28, 1916

The Board of Examiners, at its regular monthly meeting on November 28, 1916, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To the Grade Member

Barrett, Sampson Kirby, Assistant Professor of Electrical Engineering, Polytechnic Institute, Brooklyn. N,Y.

Bliss, Louis Denton, President, Bliss Electrical School, Washington, D. C.

Dillon, Edward Paul, Assistant Manager, Railway & Lighting Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Edgecomb, Henry R., Chief Engineer, Speer Carbon Co., St. Marys, Pa.

Digitized by Google

GORSUCH, WILLIAM SCHROFIELD, Engineer of Economics, Interborough Rapid Transit Co., New York, N. Y.

GREENLAND, SAMUEL WILSON, General Manager, Fort Wayne & Northern Indiana Traction Co., Fort Wayne, Ind.

STEVENOT, J. E. HAMILTON, Constructing and Consulting Electrical Engineer, Manila, P. I.

TRANSFERRED TO THE GRADE OF FELLOW DECEMBER 8, 1916

The following Member was transferred to the grade of Fellow of the Institute at the meeting of the Board of Directors on December 8, 1916.

HAVILL, O. A., Electrical Engineer, Viele, Blackwell & Buck, New York, N. Y.

TRANSFERRED TO THE GRADE OF MEMBER DECEMBER 8, 1916

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on December 8, 1916.

CARROLL, EMIL J., Electrical Engineer, American Laundry Machine Co., Cincinnati, O.

CHAMBERLAIN, F. G., Vice-President, Tuttle, Chamberlain & Co., San Antonio, Tex.

GOODING, ROBERT F., Switchboard Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GOODWIN, HAROLD, JR., Superintendent of Distribution, Philadelphia Electric Co., Philadelphia, Pa.

HECKER, GUY C., Chief Electrician, Pittsburgh Railways Co., Pittsburgh, Pa.

KENYON, OTIS ALLEN, Engineer, Arc Welding Machine Co., New York, N. Y.

NASH, LUTHER R., Public Utility Expert, Stone & Webster Management Association, Boston, Mass.

NISAR, A. R., Head Assistant Professor, Electrical Dept., Central Technological Institute, Bombay, India.

STEWART, HAROLD O., Engineer, Industrial Dept., Rochester Railway & Light Co., Rochester, N. Y.

TAYLOR, WILLIAM B., Engineer of Insulation Dept., General Electric Co., Lynn, Mass.

THOMAS, GEORGE B., Professor of Electrical Engineering, Colorado College, Colorado Springs, Colo.

MEMBERS ELECTED DECEMBER 8, 1916

CARVER, HARRY EUGENE, Asst. Engineer and Electrical Inspector, Public Utility Commission, Kinney Bldg., Newark; res., East Orange, N. J.

COPE, HAROLD WHITCOMB, Assistant to Manager of Engineering, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 7225 Meade St., Pittsburgh, Pa.

*NELSON, JOSEPH MARCY, Superintendent of Construction, J. G. White Engineering Corp., Pottsville; res., Chester, Pa.

RAYMOND, FREDERIC ARCHER, Insurance Engineer, National Board of Fire Underwriters, 76 William St., New York, N. Y.; res., 38 Lawrence Ave., West Orange, N. J.

*Former enrolled Student.

ASSOCIATES ELECTED DECEMBER 8, 1916

BERGLAND, ERIC LEONARD, Engineering Dept., E. I. Du Pont de Nemours & Co., Du Pont Bldg.; res., Brandywine Apts., Wilmington, Del.

*BRINKMEIER, ARNOLD EDWARD HUGO, High Tension Substation Operator, Electric Co. of Missouri; res., 6215 Page Ave., St. Louis, Mo.

CAVALCANTI, LEONARDO DE ALBUQUERQUE, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 732 Hill Ave., Wilkinsburg, Pa.

CORKRAN, JAMES G., Wireman, Panama Canal, Cristobal, Canal Zone.

Digitized by Google

CORNEY, CHESTER ALBERT, Electrical Designer, Stone and Webster Engineering Corp., Boston; res., 781 Broadway, South Boston, Mass.

DEANS, WILLIAM, Instructor in Electrical Engineering, Sibley College, Cornell University; res., 903 N. Cayuga St., Ithaca, N. Y.

*DIAMANT, NICHOLAS S., Instructor in Engineering, Rice Institute, Houston, Texas.

*FERNANDEZ-MAREQUE, FRANCISCO, Electrical Engineer, Ferro Carril Central del Paraguay; res., Avenida Ascuncion No. 367, Asuncion, Paraguay, South America.

*FICK, CLARENCE WILLIAM, Assistant Foreman, General Electric Co., Schenectady; res., Ballston Lake, N. Y.

*FROMMELT, HORACE A., Student of Letters, St. Stanislaus Seminary, Florissant, Mo.

GANTER, ERNEST LINWOOD, Assistant Inspector, Dominion Government Gas and Electric Dept.; res., 115 Leinster St., St. John, N. B.

*GAZDA, ADOLPH ANDREW, Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 835 Rebecca Ave., Wilkinsburg, Pa.

GERBER, LIPMAN S., Detail Engineer, Switchboard Dept., General Electric Co.; res., 618 Chapel St., Schenectady, N. Y.

GILMOUR, ALEJANDRO DRYBURGH, Superintendent Engineer, Compania de Salitre y Ferro-Carril de Junin, Alto de Junin, Iquique, Chile, S. A.

GOULD, RUSSELL, Superintendent of Power, Northern Electric Railway; res., 932 Butte St., Chico, Cal.

HANFF, EDWARD ATLEE, Chief Engineer, Penn Electrical & Mfg. Co.; res., 617 Walnut St., Irwin, Pa.

HAWKINS, PAUL DARWIN, Service Manager, Industrial Service & Equipment Co., 100 Sumner St., Boston, Mass.

*HOLTZ, FREDERICK CARL, Instructor in Electrical Engineering, University of Nebraska; res., 1636 M St., Lincoln, Nebr.

HUFF, ERNEST LOUIS, Electrical Engineer, Pennsylvania Salt Mfg. Co.; res., Federal St., Natrona, Pa.

JONES, CHARLES RAMEY, Westinghouse Electric & Mfg. Co., New York, N.Y.; res., 238 State St., Hackensack, N. J.

JONES, EDWIN ERIE, Switchboard Operator, Lewis St. Plant, Union Electric Light & Power Co., St. Louis, Mo.

JONES, ROBERT AUSTIN, Engineering Dept., Society for Electrical Development, 29 W. 39th St.; res., 524 W. 123rd St., New York, N. Y.

KILE, ROY BROOK, Engineering Dept., Duquesne Light Co., Pittsburgh; res., 302 Gray Apts., Wilkinsburg, Pa.

*KIRK, RALPH LEVERING, Electrical Designer, Duquesne Light Co., Pittsburgh; res., Y. M. C. A., East Liberty, Pa.

*KIVLIN, ALFRED PATRICK, Appraisal Engineer, Public Utility Commission, Newark, N. J.; res., 43 School St., N. Attleboro, Mass.

LAMB, HOWARD LUIS, Office and Construction Work, Otis Elevator Co., Casilla 3760, Santiago, Chile, South America.

LEEDOM, RANDOLPH, Engineering Assistant to Construction Engineer, Western Union Telegraph Co., 195 Broadway, New York; res., 35 E. 7th St., Brooklyn, N. Y.

LEVVY, ALBERT, Managing Director, Levvy Electrical Co. Ltd.; res., 1300 Wolseley Ave., Winnipeg, Man.

LINDSEY, JAMES K., General Foreman, Electric Dept., Firestone Tire & Rubber Co.; res., 296 E. South St., Akron, O.

LYLE, JAMES W., Division Engineer, Texas Power & Light Co.; res., 209 N. Waco St., Hillsboro, Tex.

LYTLE, JAMES H., Engineer, Penn Public Service Co.; res., 314 Walnut St., Clearfield, Pa.

MANNING, STANLEY RUTTER, Electrical Equipment Engineer, Michigan State Telephone Co.; res., 958 Trumbull Ave., Detroit, Mich.

Digitized by Google

MASON, GEORGE ERIC, President and Managing Director, Lancashire Dynamo & Motor Co. of Canada Ltd., 107 Duke St.; res., 17 Kingswood Rd., Toronto, Ont.

*MCAFEE, WILLIAM KEITH, Railway Engineering Div., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., Clover Club, Edgewood Park, Pittsburgh, Pa.

MOULTROP, NORMAN IRVING, Electrical Engineering Dept., Edison Electric Illuminating Co. of Boston, Boston; res., 75 Winchester St., Brookline, Mass.

ORT, CARL, Engineering Dept., Western Electric Co., 463 West St.; res., 544 W. 150th St., New York, N. Y.

OSBORNE, CHARLES PARKER, Supt. of Power, Portland Railway, Light & Power Co., Electric Bldg.; res., 761 Clinton St., Portland, Ore.

PRESS, ABRAHAM, Assistant Professor of Electrical Engineering, Oklahoma University, Norman, Okla.

QUIRK, WILLIAM G., Supervising General Inspector in Charge of Street Lighting and Electrical Conductors, Dept. of Water Supply, Gas and Electricity, New York, N. Y.

ROBERTSON, FREDERICK JOHN, General Superintendent, Calgary Power Co. Ltd., Seebe, Alberta, Canada.

*SHAW, ALEXANDER MARSHALL THOMPSON, Electrical Engineer, Laboratory, Philadelphia Electric Co., Philadelphia; res., Wayne, Pa.

SIMPSON, ALSTON RAYMUR, Lieutenant U. S. Navy; res., 415 W. 118th St., New York, N. Y.

*SMITH, LEWIS MARTIN, Draftsman, Tennessee Coal, Iron and Railroad Co., Ensley; res., 2216 12th Ave. N., Birmingham, Ala.

SMITH, ROBERT WILEY, Electrical Engineer, Columbus Power Co.; res., Chatham Drive, Columbus, Ga.

STEIN, SAMUEL, Senior Student, Polytechnic Institute of Brooklyn; res., 235 W. 111th St., New York, N. Y.

STEVENS, EDSON MURRAY, Consulting Engineer, Commerce Building; res., 2930 Olive St., Kansas City, Mo.

STURZ, FREDERICK, JR., Cadet Engineer, New York Edison Co., 15th St. & Irving Place; res., 755 Dawson St., New York, N. Y.

TOMANN, ORVILLE RAYMOND, Electrical Engineer, Red Oak Electric Co., 210 Coalbaugh St., Red Oak, Ia.

TREMAINE, A. RAYMOND, Manager, Depew and Lancaster Light, Power and Conduit Co., 173 Central Ave.; res., 41 Maple Ave., Lancaster, N. Y.

TRINKLE, ROBERT JACOB, Electrician, DuPont Powder Works, "A" Plant; res., 402 S. 2nd St., Hopewell, Va.

WALTERS, DONALD GRIBBEN, Student, Telephone Plant Dept., New York Telephone Co., New York; res., 433 Dean St., Brooklyn, N. Y.

WEI, WING LOCK, Graduate Student, Union University; res., 131 Glenwood Blvd., Schenectady, N. Y.

WELLER, FRANK RUDOLPH, Superintendent, Lamp Factory, Vosburgh Mine Lamp Co., West Orange, N. J.; res., Krischerville, S. I., N. Y.

WELLS, JAMES HAROLD, Electrical Draughtsman, Engineering Dept., Edison Electric Ill. Co. of Brooklyn; res., 2604 Newkirk Ave., Brooklyn, N. Y.

WHALER, H. THOMPSON, General Manager, Miami Telephone Co., Miami, Fla.

WHATELY, HAROLD ELKRIDGE, Hydro-Electric Power Commission; res., 102 Arundel Ave., Toronto, Ont.

WILLIAMS, EDWIN PURNELL, Professor of Electrical Engineering and Physics, University of New Brunswick; res., 3 Lansdowne St., Fredericton, N. B.

*WISEMAN, ROBERT JOSEPH, Research Assistant, Elec. Engg. Dept., Massachusetts Institute of Technology, Boston; res., Arlington, Mass.

Total 58.

*Former enrolled Students.

Digitized by Google

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before January 31, 1917.

Anderson, G. L., Philadelphia, Pa.
Asire, H. W., South Bend, Ind.
Barns, F. B., Philadelphia, Pa.
Bernhard, A. H., Brooklyn, N. Y.
Bertrand, W. E., Woodbine, N. J.
Bradshaw, W. M., E. Pittsburgh, Pa.
Burbeck, W. B., San Francisco, Cal.
Butcher, W. F., Yonkers, N. Y.
Chadwick, R. H., Ft. Wayne, Ind.
Cutting, F. (Member), Cambridge, Mass.
Delehanty, W. J., San Francisco, Cal.
Egee, G. B., Philadelphia, Pa.
Epps, W. J., Rio de Janeiro, Brazil
Fallon, W. A., Montrose, Colo.
Faulkner, L. W., Champaign, Ill.
Ferguson, R. S., Pasadena, Cal.
Fisher, C. W., Philadelphia, Pa.
Gibson, O., San Francisco, Cal.
Guest, H. E., Worcester, Mass.
Hansen, H. C., Bristol, Va.-Tenn.
Hayward, T. J., Panama, R. P.
Himmelsbach, J. R., Seattle, Wash.
Horner, O. H., Kansas City, Mo.
Howard, D. G., Pittsburgh, Pa.
Hoye, J. P., Detroit, Mich.
Huber, W. E., Cleveland, O.
Johnson, J. H., Chelmsford, England.
Kehl, R. J., Chicago, Ill.
Kewin, G. E., Toronto, Ontario.
Kistler, R. E., Pittsfield, Mass.
Kraft, C. H., St. Louis, Mo.
Krey, B. H., New York, N. Y.
LaFever, H. H., New York, N. Y.
Lais, R. A., Cleveland, O.
Ledermann, F., Brooklyn, N. Y.
List, E. G., Olmsted, Utah.
Mahan, J. H., Philadelphia, Pa.
Mahoney, J. N. (Fellow), East Pittsburgh, Pa.
McGowan, H. E. (Member), Brooklyn, N. Y.
McGuire, J. P., Schenectady, N. Y.
McLay, A. D., Detroit, Mich.
Melnikoff, N. P. (Member), Petrograd, Russia.
Mendenhall, C. A., San Francisco, Cal.
Mertz, K. J., St. Paul, Minn.
Metzger, A. B., New York, N. Y.
Morey, L., Cleveland, O.
Morrow, L. O., Philadelphia, Pa.
Mundo, C. J. (Member), Pittsburgh, Pa.
Munroe, H.K. (Member), Tacoma, Wash.
Nakamura, Y., Yamaguchi-ken, Japan.
Nelson, J. E., Cleveland, O.
Noe, E. T., Jr., Philadelphia, Pa.
Nordfeldt, H. B. E., Vasteras, Sweden.
Norton, F. A., Milwaukee, Wis.
Notvest, G. R., Cleveland, O.
Pattee, C., Hood River, Ore.
Perry, W. W., Easton, Pa.
Reed, A. J., San Francisco, Cal.
Riley, L. G., East Pittsburgh, Pa.
Ritter, J. B., Philadelphia, Pa.
Roberts, S., Harrisburg, Pa.
Robinson, G. D., State College, Pa.
Rudin, O. W., Anderson, Ind.
Salberg, J., Denver, Colo.
Schnake, H. C., New York, N. Y.
Schneider, S., Coney Island, N. Y.
Scott, M., Akron, O.
Shand, E. B., East Pittsburgh, Pa.
Smiley, G. W., Detroit, Mich.
Sticht, R. E., Spokane, Wash.
Stokes, C. W., Montreal, Que.
Sullivan, F. J., Detroit, Mich.
Taylor, A. R., Sedalia, Mo.
Tear, H. R., Springfield, Ill.
Toyomura, C., Sukegawa, Japan.
Weiss, C. G. A., New York, N. Y.
Wikle, H. H., Cleveland, O.
Williams, L. H., Atlanta, Ga.
Wilson, J. R., Pittsburgh, Pa.
Winder, W. A., East Pittsburgh, Pa.
Wolf, K., New York, N. Y.
Woodward, C. V., Philadelphia, Pa.

Total 82.

Digitized by Google

STUDENTS ENROLLED DECEMBER 8, 1916

8486 Reed, M. G., Yale Univ.
8487 Eggen, C. B., Univ. of Kansas.
8488 Williams, F. J., Univ. of Minn.
8489 Ekenbeck, E. E., Univ. of Minn.
8490 Wheeler, H. H., Univ. of Minn.
8491 Turnquist, A. A., Univ. of Minn.
8492 Blomberg, E. H., Univ. of Minn.
8493 McKibben, R., Univ. of Minn.
8494 Miller, G. W., Univ. of Minn.
8495 Mitchell, A. C., Univ. of Minn.
8496 Smith, D. C., Univ. of Minn.
8497 Bauer, R. B., Univ. of Minn.
8498 Hotchkiss, F. W., Univ. of Minn.
8499 Schlenk, H., Jr., Univ. of Minn.
8500 Ross, R. H., Univ. of Minn.
8501 Baker, R. R., Univ. of Michigan
8502 Bassett, H. B., Univ. of Mich.
8503 Conaut, H. D., Univ. of Mich.
8504 Cook, R. H., Univ. of Mich.
8505 Crump, S. L., Univ. of Mich.
8506 Davis, R. L., Univ. of Mich.
8507 Dietze, E., Univ. of Michigan
8508 Hauser, O. E., Univ. of Mich.
8509 Heath, G. S., Univ. of Mich.
8510 Henschel, E. W., Univ. of Mich.
8511 Kendall, E. N., Univ. of Mich.
8512 Little, D. G., Univ. of Mich.
8513 Meyers, M. G., Univ. of Mich.
8514 Petermann, F. K., Univ. of Mich.
8515 Petrie, G. R., Univ. of Mich.
8516 Strachan, O. W., Univ. of Mich.
8517 Thoms, L. W., Univ. of Mich.
8518 Whitney, J. H., Univ. of Mich.
8519 Wise, S. J., Clarkson Coll. Tech.
8520 Bruce, F. C., Lewis Institute.
8521 Ardern, E. W., Marquette Univ.
8522 Canavaciol, F.E.,Bklyn.Poly.Inst.
8523 Wehle, P. G., Brooklyn Poly. Inst.
8524 Pomeroy, W. C., Univ. of Calif.
8525 Birkinbine, O. W., Univ. of Penna.
8526 Rothschild, H. L., Univ. of Minn.
8527 Whitfield, H. B., Univ. of Nebr.
8528 Horning, A. W., Case School of Applied Science.
8529 Weyl, C. N., Univ of Penna.
8530 Ewing, R. P., Penna. State Coll.
8531 Dailey, C. O., Purdue Univ.
8532 Parsell, L. B., Purdue Univ.
8533 Raphael, V., Lewis Institute.
8534 Ellzey, C. C., Jr., Univ. of Ala.
8535 Butterwoth, R. I., Univ. of Minn.
8536 Bach, R. O., Univ. of Washington.
8537 Storrow, J.J.,Jr.,Mass. Inst.Tech.
8538 Correia, J. N., Mass. Inst. Tech.
8539 Warner, R. W., Univ. of Kansas.
8540 Hyatt, S. M., Tri-State College.
8541 Petzing, E.W., Armour Inst. Tech.
8542 Thrall, E. F., Yale University.
8543 Appleman,G.,Penna.State College
8544 Cahoon, A. W., Yale Univ.
8545 Bond, L. W., Penna. State Coll.
8546 Eggert, W. C., Mich. Agri. Coll.
8547 Swenson, S. R., Yale Univ.
8548 Cunningham, L., Mass. Inst.Tech.
8549 Buckley, D. J., Stevens Inst.
8550 Nettleton, L. A., Yale Univ.
8551 Ruiz, J. J., Cornell Univ.
8552 Etshokin, L., Cornell Univ.
8553 Weigt, J. W., Cornell Univ.
8554 Stahl, G. D., Cornell Univ.
8555 Gates, J. G., Cornell Univ.
8556 Timmerman, A. P., Cornell Univ.
8557 Bitner, R. E., Cornell Univ.
8558 Hatch, F.A.,ClarksonColl.ofTech.
8559 McConnell, D. F., Univ. of N. D.
8560 Green, J. L., Univ. of N. D.
8561 Hicks, F. T., Univ. of N. D.
8562 Hills, H. G., Case Sch. App. Sci.
8563 Farnham, R. E., Case Sch. of App. Sci.
8564 Schoonmaker,LE.,Mass.Inst.Tech.
8565 Fleming, G. A., Univ. of Calif.
8566 Connor, J. M., W. Va. Univ.
8567 Shetzline, R. A., Univ. of Penna.
8568 Forbes, A. H., Yale Univ.
8569 Allen, J. P., Yale Univ.
8570 Crutcher, M. J., Univ. of Ky.
8571 Schrader, C. C., Univ of Ky.
8572 Pendleton, M., Univ. of Ky.
8573 Becker, W. E., Univ. of Minn.
8574 Herrick,W.J.,ClarksonColl.ofTech.
8575 Brenton, W., Cornell Univ.
8576 Polson, A. V., Cornell Univ.
8577 Wheeler, W. J., Cornell Univ.
8578 Jones, T. R., Cornell Univ.
8579 Weber, G. L., Colorado Coll.
8580 Clough, P. F., Clarkson Coll. of Tech.

Total 95.

Digitized by Google

EMPLOYMENT BULLETIN

Vacancies.—The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN. The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) of will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-188. Wanted: Electrical Engineer with practical experience in the design, manufacture and application of direct-current motors and controllers for hoisting service, electric cranes, etc. Must have good training, technical education, and ability to work into responsible position. Reply should give full particulars of previous employment, experience, salary expected, etc.

V-189. Wanted: Chief Draftsman with experience in the design of hoisting apparatus, electric, cranes, etc. Reply fully regarding experience, salary expected, etc.

V-191. Electrical Draftsman wanted on power and high-voltage substation designing.

V-194. A public service company, located in Maine, has openings for one or two recent technical graduates in its operating department. Opportunity for advancement according to ability. Moderate salary to start.

V-195. A Boston sales organization has openings for several young men, preferably with technical training and experience in selling electrical machinery. Give particulars.

V-196. Technically educated man with some business experience wanted in New York by publisher of high grade engineering literature, to assist in editing of technical manuscripts, also correspondence and other office work. Knowledge of good English essential. State age, nationality, education, experience in detail, and salary expected.

The U. S. Civil Service Commission announces an examination to be held at numerous places in the United States on January 17, and another on March 14, for the position of Assistant Examiner in the Patent Office. Entrance salary $1500. Applicants should have a general knowledge of physics, mathematics, mechanics, chemistry, etc. Practically all applicants who pass this examination are appointed. Those desiring this examination should at once apply for Circular No. 36 describing the test, application Form No. 1312, and a copy of the Manual of Examinations for the Fall of 1916, to the U. S. Civil Service Commission, Washington, D. C.

MEN AVAILABLE

625. Graduate Electrical Engineer (Univ. Penn.), with two years power station experience, seeks position with consulting engineer or with company engaged in the design, construction, etc., of power plants. Locality of Philadelphia preferred.

626. Superintendent or Engineer for central station or large consumer. Graduate of technical college and Westinghouse apprenticeship course. Eight years' electrical experience, including five years' meter and complaint work with large central station. Age 31; married; teetotaler; now employed. Have never lost a day's work account sickness or accident.

627. Mechanical or Electrical Engineer, technical graduate (1902), with extensive experience, testing operating, constructing, designing, selling, purchasing, public utility reports, office engineering and consulting. Have been continually employed since graduation. Now holding executive and engincering position of responsibility. Salary $3-500.

628. Electrical and Mechanical Engineer, native of Sweden, age 27, with good experience in testing, power station design, transmission lines, transformers and general engineering subjects, desires a position with a reliable concern interested in the establishing of an efficient foreign trade, especially to Scandinavia and Russia.

Digitized by Google

629. Induction Motor Engineer. Ten years with three leading manufacturers. Open January first. Designed and built fractional horse power to largest in operation. Prepared to take complete charge of engineering. Excellent record; young, hustler and strictly up on modern design. No obsolete methods used. Services reasonable to right party. Interview or references.

630. Fellow A. I. E. E., Mem. A. S. M. E., F. I., etc., with broad business and technical training and experience desires position as executive, manager or in organization work. Familiar with shop practise, organization, cost systems, etc. Wide experience in operation of power wagons, in their design, construction and purchase. Sales Engineer.

631. Electrical Engineer. Ten years' practical experience in applied electricity. Can competently handle the following: Erection and maintenance of transmission lines, all classes. Installation and operation of a-c. and d-c. generators, motors, switchboards, and can do rewinding; also all classes of interior wiring. Age 28.

632. Young Electrical Engineer, 1916 graduate, desires position in a growing concern dealing in electrical supplies. Capable of developing and handling domestic or foreign trade. Salary a secondary consideration where opportunity for advancement is offered. At present employed.

633. Superintendent or Sales Engineer, Mem. A. I. E. E., 35, married. Fifteen years' experience in manufacture and sale of electrical machinery; at present employed; seeks new position requiring initiative and executive ability.

634. Railroad and Power work. Graduate electrical engineer, age 28, desires position in power or engineering department of electrified railroad or traction system. Six years' experience with large central station company on construction, operating, engineering and testing work. Any location. Expect good opportunities for advancement.

635. Graduate Electrical Engineer. Experienced in the operation of central station machinery and also installation of motors, circuit-breakers, conduit work and transformers, desires to locate with some large electrical construction firm or with a consulting engineer who needs an experienced man for field work. Desires opening with good chance for advancement. At present employed.

636. Electrical Engineer, two years, seven months sales engineering experience, age 27. One with executive ability; aggressive; desires position in New York or vicinity. A $3000 man.

637. Engineer, specialist and recognized expert in public utility and industrial power work, offers full or part time services to firm or corporation interested in such properties. Broad experience in the design, construction and operation of power systems and in making investigations, appraisals and reports covering going and projected enterprises.

638. Engineer, Technical graduate, in charge of erection and design of plant and equipment for large chemical concern, wishes to change. Can purchase equipment to good advantage and install it so as to most economically utilize available floor space. Will soon be open for engagement. $2100 to start.

639. Electrical Engineer, technical education and fifteen years' experience in responsible charge electrical departments large industrial, mining and smelting plants. Accustomed to handling men successfully as well as engineering problems, both operating and construction. Open for engagement after January 1. Mem. A. I. E. E.

640. Public Utilities Engineer, technical graduate, with ten years' practical experience in both electricity and gas; some street railway. Previous work covers construction, operation, purchasing, valuations and syndicate management. Has held positions of chief engineer and general superintendent. Desires responsible position on operating or managing staff. Chicago or New York interview preferred.

641. Electrical Engineering Graduate (1914), 2½ years in testing department of public service company, seeks position in engineering department of similar or manufacturing company. At present employed.

642. Light and Power Engineering. Ten years' experience in construction, management, designing and testing. Experienced in analyzing operating results from both financial and technical standpoint. Degree of E. E. from Columbia University.

643. Comptroller-General Auditor; age 36; Certified Public Accountant; attorney-at-law; specialist in the finances and accounts of public utilities, particularly electric light and power companies; well connected but interested in a broader field.

644. Construction or Maintenance Engineer, 24 years' experience in electric

Digitized by Google

railway and lighting construction and operation, chiefly in the railway field. Has specialized in power and substation and overhead construction. Now employed; available on short notice; will go anywhere.

645. Graduate Electrical Engineer, age 35, with fifteen years' utility experience, including design, construction, operation and responsible executive work with railway, light and power, and high-tension transmission systems; now employed as superintendent of distribution and construction. Member of Transmission Committee two years. Prefers position of responsibility with electrified steam road.

ACCESSIONS TO LIBRARY

This list includes books which have been presented to the library of the A. I. E. E. and the U. E. S. during the past month, not including periodicals and other exchanges.

American Institute of Electrical Engineers. Standardization Rules. October, 1916.

Lloyd's Register of Shipping. Report of the society's operations 1915-16. London, n.d. (Gift of Lloyd's Register of Shipping.)

Washington Academy of Sciences. McGee Memorial Meeting held at Carnegie Institution, Dec. 5, 1913. Baltimore, 1916. (Gift of Washington Academy of Sciences.)

Wallingford (Conn.) Board of Electrical Commissioners. Report of Borough Electric Works year ending July 31, 1916. (Gift of Alfred L. Pierce.)

UNITED ENGINEERING SOCIETY

Bibliography—Spontaneous combustion and weathering of coal. (Gift of Edwin B. Ricketts.)

Mechanics of Telephone Receiver Diaphragms, as derived from their motional impedance circles. By A. E. Kennelly and H. A. Affel. (Massachusetts Institute of Technology. Electrical Engineering Dept. Bulletin No. 8, Nov. 1915.) Reprinted from the Amer. Academy of Arts and Sciences. Proc. Nov. 1915. (Gift of Massachusetts Institute of Technology, Electrical Engineering Dept.)

Valuation of the National Association of Railway Commissioners, Report of the Committee. Scope of the Committees' Jurisdiction. Nov. 1916. (Gift of Clemens Herschel).

Charlotte, N. C. Code of the City. Charter and Ordinances, July 1914. Charlotte, 1915. (Gift of the City Clerk).

Norfolk, Va. Tentative report. Proposed building ordinances March 25, 1915. (Gift of City Clerk.)

Krause Absorbent Filter. Pure and safe feed water from oily condensate of all kinds guaranteed by using. (Gift of A. E. Krause.)

Hill, John A. Some of the writings of. (Gift of Power.)

Regeln für Leistungsversuche an Ventilatoren und Kompressoren. Aufgestellt vom Verein deutscher Ingenieure und dem Verein deutscher Maschinenbau Anstalton im Jahre 1912. (Gift of Leon Goldmerstein.)

New York Electric Railway Association. Annual Report. 31st-33d. v. p. 1913-15. (Gift of Association.)

Federal Valuation of the Railroads in the United States. List of Valuation Committees of the railroad companies and principal officers and employes of the Interstate Commerce Commission engaged in appraisal work. October, 1916. Philadelphia, 1916 (Gift of Clemens Herschel.)

Madison (Wis.) Industrial Commission. Building Code. 1915.

——Fire Protection in Schools. 1914.

——General Orders on Safety Building Construction. 1914.

——Proposed orders on fire protection in existing buildings including also sanitation in existing tenements and theaters. 1915. (Gift of Commission.)

Galveston (Texas) Building Dept. Building Code. 1914. (Gift of Galveston Building Dept.)

Columbia (South Carolina) Building Dept. Building Code. 1916. Columbia, 1916. (Gift of Building Department).

Elenco dei Fabbricanti in Italia di Materiale e Macchinario Elettrico. Oct. 1916. Milano. 1916. (Gift of Associazione Elettrotecnica Italiana.)

Ohio Public Utilities Commission. Annual Report. 1914, 1915.

——Laws of Ohio relating to Public Utilities, 1916

Rules of practice before the commission. 1916. (Gift of Public Utilities Commission.)

Institution of Mechanical Engineers. Alloys Research Committee. Report 1st-8th and Appendix. London, 1891-1907. (Gift of Bradley Stoughton.)

Titles to Mines in the United States. By W. A. Harris, London, 1877. (Gift of Bradley Stoughton.)

Carnegie Steel Company. Pocket companion for engineers, architects, and builders, containing useful information and tables appertaining to the use of steel. Ed. 19. Pittsburgh, 1917. (Gift of Carnegie Steel Company.)

Passaic, N. J. Ordinance Concerning Streets and Public Buildings of the City. 1888. (Gift of City Clerk.)

List of Inspected Electrical Appliances, October 1916, supplement to April 1916. (Gift of Underwriters Laboratories.)

Catalogue Studies. vols. 1, 4, 6, 7, 10, 12, 15, 23, 24, 27, 28, 34, 37-40, 42, 43, 48 & index.

——Blue Print Book. 56 Prints.

Gifts of Catalogue Equipment and Supply Company.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917) **SECRETARY.**
GEORGE A HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

LIBRARIAN.
W. P. CUTTER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884 1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A E KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7.
HENRY G. STOTT, 1907-8
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to January 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.
N. A. Carle, George A. Hamilton,
John H. Finney, William McClellan,
Bancroft Gherardi, J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.
N. A. Carle, Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.
Frederick Bedell, F. W. Peek, Jr.
Philander Betts, F. L. Rhodes,
J. G. De Remer, D. W. Roper,
H. A. Hornor, Harris J. Ryan,
Edward P. Hyde, T. H. Schoepf
L. E. Imlay, Charles P. Steinmetz,
E. H. Martindale, N. W. Storer,
Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
Frederick Bedell, L. T. Robinson,
M. G. Lloyd, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
Engineers' Club, 32 West 40th Street, New York.
E. B. Katte, W. I. Slichter,
F. L. Rhodes, Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
J. G. De Remer, A. M. Schoen,
Paul M. Lincoln, J. H. Tracy,
and the chairmen of all Institute Sections, *ex-officio*.

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.
G. M. Baker W. G. Chace,
S. H. Blake, H. W. Flashman,
E. H. Martindale.
and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
E. A. Carolan, William McClellan,
John J. Carty, H. H. Porter,
Fredk. Darlington, C. S. Ruffner,
Gano Dunn, A. M. Schoen,
John B. Fisken, L. B. Stillwell,
A. M. Hunt, H. G. Stott.

COMMITTEE ON DEVELOPMENT OF WATER POWER.

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.
F. O. Blackwell, E. A. Lof,
Francis Blossom, W. V. N. Powelson,
Gano Dunn, L. B. Stillwell,
Nicholas S. Hill, Jr., H. G. Stott.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Harvard University, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, H. D. James,
Frederick Bedell, P. Junkersfeld,
Joseph Bijur, A. E. Kennelly,
L. F. Blume, G. L. Knight,
James Burke, A. S. McAllister,
G. A. Burnham, W. M. McConahey,
N. A. Carle, W. L. Merrill,
E. J. Cheney, Charles Robbins,
H. H. Clark, L. T. Robinson,
E. H. Colpitts, C. H. Sharp,
F. P. Cox, C. E. Skinner,
W. A. Del Mar, A. J. Slade,
E. J. Edwards, N. W. Storer,
H. W. Fisher, H. G. Stott,
H. M. Hobart, R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTRO-TECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, E. B. Rosa,
B. A. Behrend, Charles F. Scott,
Louis Bell, Clayton H. Sharp,
James Burke, Samuel Sheldon,
John J. Carty, C. E. Skinner,
Gano Dunn, Charles P. Steinmetz,
H. M. Hobart, H. G. Stott,
John W. Lieb, Elihu Thomson,
R. B. Owens, Philip Torchio.
M. I. Pupin,

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, Charles A. Terry,
John F. Kelly, B. F. Wood.

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.

A. E. Kennelly, Chairman, Robert T. Lozier,
S. G. McMeen.

Term expires July 31, 1918.

H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.

Charles F. Brush N. W. Storer
C. C. Chesney,

Term expires July 31, 1920.

Carl Hering Harris J. Ryan
H. G. Stott.

Term expires July 31, 1921.

W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.

B. A. Behrend, Paul M. Lincoln,
William McClellan.

Term expires July 31, 1918.

C. A. Adams, Harold Pender,
C. E. Skinner.

Ex-Officio.

H. W. Buck, President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to January 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
100 Broadway, New York.

J. M. Drabelle,	R. J. S. Pigott,
C. C. Egbert,	Cecil Poole,
W. S. Gorsuch,	E. F. Scattergood,
John Harisberger,	P. A. Scheffler,
A. H. Kruesi,	H. G. Stott,
Paul M. Lincoln,	W. R. Thompson,
Wynn Meredith,	Philip Torchio,
J. E. Moultrop,	H. L. Wallau,
S. A. Moss,	B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,	P. M. Lincoln,
M. T. Crawford,	W. E. Mitchell,
E. E. F. Creighton,	G. J. Newton,
H. H. Dewey,	L. C. Nicholson,
P. M. Downing,	W. D. Peaslee,
H. W. Fisher,	Stefaan Piek,
P. A. Gaby,	C. S. Ruffner,
W. T. Goddard,	H. J. Ryan,
O. A. Havill,	F. D. Sampson,
R. F. Hayward,	H. E. Shedd,
J. P. Jollyman,	Julian C. Smith,

P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman,
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,	P. J. Kearny,
A. H. Babcock,	William McClellan,
Reinier Beeuwkes,	John Murphy,
E. J. Blair,	W. B. Potter,
L. P. Crecelius,	E. D. Priest,
J. V. B. Duer,	Charles H. Quinn,
George Gibbs,	Clarence Renshaw,
W. J. Harvie,	A. S. Richey,
Hugh Hazelton,	Charles F. Scott,
E. B. Katte,	John B. Taylor,

H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,	G. A. Johnstone,
J. H. Davis,	C. A. Kelsey,
James Dixon,	C. L. Kennedy,
A. M. Dudley,	Charles D. Knight,
Herbert B. Dwight,	A. H. Lawton,
F. W. Ells,	A. M. MacCutcheon,
J. E. Fries,	A. G. Pierce,
F. R. Fishback,	James M. Smith,
R. H. Goodwillie,	H. Weichsel,
A. L. Hadley,	J. B. Wiard,

R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,	Richard C. Powell,
C. E. Clewell,	E. B. Rosa,
J. R. Cravath,	W. D'A. Ryan,
T. S. Perkins,	Clayton H. Sharp,

W. M. Skiff,

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,	William McClellan,
W. H. Blood, Jr.,	Norman C. McPherson,
Fred A. Bryan,	Allard Smith,
C. L. Cory,	H. G. Stott,
Harry Clifford Eddy,	W. G. Vincent,
W. B. Jackson,	George W. Whittemore,
A. H. Kruesi,	G. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman
Room 500, 72 W. Adams St., Chicago, Ill.

L. L. Elden,	A. A. Meyer,
G. Faccioli,	L. C. Nicholson,
V. E. Goodwin,	N. L. Pollard,
E. M. Hewlett,	S. D. Sprong,
Paul M. Lincoln	Philip Torchio,

H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,	F. G. Liljenroth,
F. A. J. Fitzgerald,	Eugene F. Roeber,
A. F. Ganz,	J. A. Seede,
F. A. Lidbury,	R. Tschentscher,

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,	E. B. Rosa,
A. C. Crehore,	Harris J. Ryan,
G. Faccioli,	Clayton H. Sharp,
C. L. Fortescue,	C. P. Steinmetz,
W. S. Franklin,	P. H. Thomas,
A. E. Kennelly,	J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
15 Dey St., New York.

E. F. W. Alexanderson,	Kempster B. Miller,
R. E. Chetwood,	H. Mouradian,
M. M. Davis,	W. O. Pennell,
C. L. Fortescue,	Allard Smith,
H. M. Friendly,	John S. Stone,
F. B. Jewett,	John B. Taylor,
S. M. Kintner,	J. L. Wayne, 3rd,
Wm. Maver, Jr.,	G. M. Yorke.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.
D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,	Guy Hill,
M. W. Day,	O. P. Loomis,
G. E. Edgar,	G. A. Pierce, Jr.,
W. L. R. Emmet,	H. M. Southgate,
W. R. Furlong,	E. A. Sperry,
H. L. Hibbard,	Wilfred Sykes,

F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,	L. C. Ilsley,
Frank H. Armstrong,	R. L. Kingsland,
Graham Bright,	Charles Legrand,
W. A. Chandler,	Charles M. Means,
F. J. Duffy,	K. A. Pauly,

H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,	A. G. Pierce,
F. B. Crosby,	J. C. Reed,
E. Friedlaender,	R. Tschentscher,
E. S. Jefferies,	Brent Wiley,
D. M. Petty,	R. B. Williamson

J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman.

Alexander Gray,	William McClellan,
E. J. Henkhe,	Chester W. Rice,
E. A. Loew,	C. E. Skinner,

R. D. Thomson.

Digitized by Google

SPECIAL COMMITTEES.

Revised to January 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N..Y
F. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman;
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. F. Scott.

PROPOSED RESERVE CORPS OF ENGINEERS.

Bion J. Arnold, Chairman,
105 South La Salle Street, Chicago, Ill.
John Harisberger, A. M. Schoen,
Ralph D. Mershon, Charles W. Stone.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S. McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

Ralph D. Mershon, Paul M. Lincoln,
C. O. Mailloux, John J. Carty.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Harold Pender, Edward D. Adams,
W. I. Slichter, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan,
John J. Carty.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON JOINT NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly, H. G. Stott.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand.
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.
A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa

Digitized by Google

LIST OF SECTIONS

Revised to January 1, 1917.

Name and when Organized	Chairman	Secretary
A[illegible]ta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg. Atlanta,Ga.
[illegible]more.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St.,Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, American Electrical Heater Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	Walter A. Black, 3042 Graceland Ave., Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	Gordon Campbell	M. B. Carroll, G. E. Co., West Lynn, Mass.
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7, '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, Pacific Power and Light Co., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	Lucien Buck, 1416 Lake Avenue, Rochester N. Y.
St. Louis.....Jan. 14, '03	A McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	E. T. J. Brandon	Wills Maclachlan, 910 Excelsior Life Building, Toronto, Ont.
Urbana.....Nov. 25, '02	I. W. Fisk.	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D.C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	A. Dickie	G. B. Hanson, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazier, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University....May 17, '10	N. J. Rehman	E. C. Hageman, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Marc Holzer	A. C. Maynard, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College..Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College.....Apr. 15,' 03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09	H. W. Matson	A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	R H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	N. M. Foster	G. M. Bowman, 1517 New Hampshire, Lawrence, Kansas.
Kentucky,State Univ.of Oct. 14, '10	H. E. Melton	Margaret Ingels, 251 Delmar Avenue, Lexington, Ky.
Lafayette College.....Apr. 5, '12	SamuelMcC.Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	P. B. Woodworth	
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of....May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	K. Atkinson	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	V. L. Hollister, Station A., Lincoln, Nebr
North Carolina Col. of Agr., and Mech. Arts.....Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	Edw. Y. Keesler	W. H. Joyner, Univ. of North Carolina, Chapel Hill, N. C.
Norwich University.....June 28, '16		
Ohio Northern Univ.....Feb. 9, '12	W. C. Bedell	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University....Dec. 20, '02	H. D. Bender	L. W. Birch, 188 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	H. M. Richards	R. E. Helfner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	G. Geracimos	August Heine, State College, Pa.
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst...Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col.Mar. 14, '13	A. W. Thayer	Carl A. Burclich, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. M. Bryant	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J.H. Peebles, University, Va.
Wash, State Col. of.....Dec. 13, '07	C. H. Worthen	C. J. Melrose, State Col. of Wash., Pullman, Wash.
Washington Univ.....Feb. 6, '04	Charles A. Lieber	R. W. Macdonald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ.....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 57.

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI FEBRUARY, 1917 Number 2

A. I. E. E. MIDWINTER CONVENTION
February 14-16, 1917

The fifth annual midwinter convention of the American Institute of Electrical Engineers will be held February 14, 15 and 16, in the Engineering Societies Building, New York. There will be five technical sessions, a number of interesting inspection trips, an informal reception, and the convention will close with a dinner-dance Friday evening.

The technical sessions have been arranged by the Meetings and Papers Committee in conjunction with several of the technical committees. The papers for Wednesday's sessions refer to the heating and temperature of generators, and to protective devices. Thursday is devoted to electrophysics, three papers under this heading being scheduled for the morning session, and a lecture in the evening by Prof. R. A. Millikan on "Modern Physics". Members of the American Physical Society have been invited to participate in both of these sessions. The two sessions on Friday are to be devoted to the subjects of d-c. and a-c. motor control.

The Committee on Technical Excursions has arranged a number of inspection trips to various places of engineering interest, details of which will be found on page 33.

The Entertainment Committee has provided for an informal reception, to be held Thursday evening after the close of Prof. Millikan's lecture, and a dinner-dance at the Hotel Astor, Friday evening, will be the closing function of the convention.

All of the Convention papers are published in this issue of the PROCEEDINGS.

Registration

Each member and guest, upon registration, will receive a badge bearing his or her name, to be worn during the convention for the purpose of identification. The registration headquarters will be in the foyer of the Engineering Societies' Building, and the members are earnestly requested to register themselves and their guests promptly on arrival.

PROGRAM

Wednesday, February 14,

10:30 A.M.

Opening Address, by President H. W. Buck.

Standards Session

1. *Internal Temperatures of A-C. Generators*, by Ralph Kelly.

2:30 P.M.

Protective Devices Session

2. *Reactors in Hydroelectric Stations*, by J. Allen Johnson.
3. *The Effect of Current-Limiting Reactors in Steam Turbine Stations Under Short-Circuit Conditions*, by Paul B. Juhnke.
4. *Protection of Transformer Neutrals Against Destructive Transient Disturbances*, by Max H. Collbohm.

7:30 P.M.

Board of Directors' Dinner, Univer-

Digitized by Google

sity Club, Fifth Avenue and 54th Street, New York.

Thursday, February 15,

10:30 A.M.

Electrophysics Session

5. *Corona and Rectification in Hydrogen*, by J. W. Davis and C. S. Breese.
6. *The Electric Strength of Air*-VII, by J. B. Whitehead and W. S. Brown.
7. *Oscillating Current Circuits by the Method of Generalized Angular Velocities*, by V. Bush.

Members of the American Physical Society are cordially invited to attend this session.

2:00 P.M.

Inspection Trips. See below.

Electrophysics Committee meeting, 10th floor.

Standards Committee meeting, 10th floor.

4:00 P.M.

Board of Directors Meeting, 10th floor. Other committee meetings will be held as specified in notices to committee members.

8:00 P.M.

Lecture

Modern Physics, by R. A. Millikan, President, American Physical Society, Professor of Physics, University of Chicago.

Members of the American Physical Society are cordially invited to attend this lecture

10:00 P.M.

Informal Reception for members and guests, Institute Headquarters, 10th floor.

Friday February 16,

10:30 A.M.

D-C. Motor Control Session

8. *Industrial Controllers with Particular Reference to the Control of D-C. Motors*, by H. D. James.
9. *Analysis of Starting Characteristics of D-C. Motors*, by K. L. Hansen.

2:30 P.M.

A-C. Motor Control Session

10. *Transient Conditions in Asynchronous Induction Machines and Their Relation to Control*, by R. E. Hellmund.
11. *Performance of Polyphase Induction Motors Under Unbalanced Secondary Conditions*, by A. A. Gazda.

7:00 P.M.

Dinner-Dance at Hotel Astor.

Informal Reception

At the close of Prof. Millikan's lecture an informal reception will be held in the Institute headquarters on the 10th floor. This will be a social reunion for the purpose of renewing and extending acquaintanceship among the members and guests attending the convention. Light refreshments will be served.

Dinner-Dance

A Dinner-Dance will be held at the Hotel Astor, Broadway and 44th Street, New York, Friday evening, February 16, 1917, at 7:00 o'clock. The purpose of the dinner-dance is to provide a pleasant social function for the entertainment of the members and their guests in attendance at the convention.

The dinner will be served at 7:00 o'clock and prompt attendance is desired in order that the Entertainment Committee's arrangements may be carried out as planned.

The subscription price is $5.00 per person. This does not include wine, cigars, cigarettes, or a late supper.

The tables will accommodate eight persons each. Members are requested to make up their own tables and to state their seating preference to the committee. Communications should be addressed to the Committee on Entertainment, A. I. E. E., 33 West 39th Street, New York.

Inspection Trips

The following companies have offered an opportunity to the members and guests in attendance at the Convention

Digitized by Google

to inspect their power houses and substations with particular reference to those enumerated below. The afternoon of Thursday, February 15, 1917, has been selected for these visits, and members and guests who wish to avail themselves of this opportunity, are requested to register in the foyer of the Engineering Societies Building as promptly as possible after the opening of the Convention. Guides will accompany each party, leaving the Engineering Societies Building at 2:15 p.m.

1. Edison Electric Illuminating Company, Brooklyn, N. Y.
   Gold Street Power Station.
2. Interborough Rapid Transit Company, New York City.
   Power Station at 59th Street and North River.
   Power Station at 74th Street and East River.
3. New York Central and Hudson River R. R. Company, New York City.
   Port Morris Power House, Substations.
   Grand Central Terminal.
4. The New York Edison Company, New York City.
   Waterside Station 38th Street and First Avenue.
5. The New York Telephone Company, New York City.
   Walker Street Building, being the largest long distance central station in the world.
6. Public Service Electric Company, Newark, N. J.
   Essex Power House.

FUTURE INSTITUTE MEETINGS

March Meeting

The March meeting of the Institute will be held in Chicago, Ill., March 9, 1917, under the auspices of the Chicago Section and the Committee on Protective Devices. The official headquarters of the Institute during this meeting will be at the Hotel Sherman, where the technical sessions and committee meetings will be held. The subject of the meeting will be "Relay Practise". Two papers will be presented on this subject, one by Mr. Philip Torchio and the other by Mr. R. F. Schuchardt.

April Meeting

The April meeting of the Institute will be held in Schenectady, N. Y., April 13, 1917. The program for this meeting has not been completed but will be announced in the following issue of the PROCEEDINGS.

Annual Business Meeting

The annual business meeting of the Institute will be held in New York at the Engineering Societies Building, May 18, 1917. At this meeting the report of the Board of Directors is presented and announcement made of the election of officers for the ensuing year.

Annual Convention

The Annual Convention will be held at Hot Springs, Va., during the week beginning June 25, 1917. The headquarters of the Institute during the convention will be The Homestead Hotel.

FUTURE SECTION MEETINGS

Boston.—February 7, 1917. The Annual Engineers Dinner for Boston. The speakers will be Prof. Elihu Thomson and Mr. E. H. Hewitz, with Prof. C. A. Adams as toastmaster.

March 6, 1917. Subject: "Electric Transmission for Motor Cars". Speaker W. B. Potter.

Chicago.—February 26, 1917. Subject: "The Making of Rates after Valuation.

Fort Wayne.—February 8, 1917. Address by Mr. Harry H. Hower on "The Sleeve Valve Motor". By invitation of the Fort Wayne Automobile Trade Association.

March 8, 1917. Motion picture entitled "King of the Rails" showing evolution of transportation.

Lynn.—February 3, 1917. Annual Banquet, Boston City Club.

Digitized by Google

Spokane.—February 16, 1917. Subject: Transmission and Distribution.

March 15, 1917. Subject: "Utilization of Electricity".

A. I. M. E. NEW YORK MEETING

The 114th meeting of the American Institute of Mining Engineers will be held Monday, Feb. 19, to Thursday, Feb. 22, inclusive, 1917, at the Engineering Building, 29 West 39th St., New York. Technical sessions will be held at 10 a.m. and 2 p.m. and luncheon served at 12.30 p.m. at the Engineering Building on each of the first three days.

Monday night has been designated "College Reunion Night" and a meeting will be held at 8:30 p.m. on the fifth floor of the Engineering Building. The Annual Dinner, followed by dancing, will be given at Hotel Astor on Tuesday evening at 6:30 p.m. Wednesday evening will be devoted to an entertainment and lecture given in the auditorium of the Engineering Building at 8:30 p.m. On Thursday a special train will leave West 42nd St., between 8 and 9 a.m. for an all day excursion to West Point.

An attractive program has been arranged for the entertainment of the ladies during the time occupied by technical sessions.

1917 YEAR BOOK

The Institute Year Book for 1917 has been published and may be obtained free of charge by any member upon application to the Secretary, 33 West 39th Street, New York, by mail or otherwise.

The book, which is published primarily for distribution to prospective members in connection with the work of the Membership Committee, contains the constitution, by-laws, lists of officers and committees, alphabetical and geographical catalogues of the membership, and considerable other general information relating to the activities of the Institute.

JOHN FRITZ MEDAL

The John Fritz Medal for 1917 has been awarded to Henry Marion Howe for his investigations in metallurgy, especially in the metallurgy of iron and steel.

The John Fritz Medal Board of Award has published a book giving a history of the Medal, the Rules of Award, and illustrated biographical notices of medallists. This beautiful book may be obtained by addressing, Secretary of John Fritz Medal Board of Award, Engineering Societies Building, 33 West 39th Street, New York. Price $3.00 per copy.

DIRECTORS' MEETING PITTSBURGH, PA., JANUARY 12, 1917

The regular monthly meeting of the Board of Directors was held at the Duquesne Club, Pittsburgh, Pa., on Friday January 12, 1917, at 3:00 p. m.

There were present: President H. W. Buck, New York; Past President Paul M. Lincoln, Pittsburgh, Pa.; Vice-Presidents C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., B. A. Behrend, Boston, Mass., P. Junkersfeld, Chicago, Ill., and L. T. Robinson, Schenectady, N. Y.; Managers John H. Finney, Washington, D. C., Harold Pender, Philadelphia, Pa., C. E. Skinner, Pittsburgh, Pa., Chas. S. Ruffner, St. Louis, Mo., and Charles Robbins, Pittsburgh, Pa.

Announcement was made of the following committee appointments by the President since the December meeting.

Educational Committee: W. I. Slichter, Chairman, Alexander Gray, E. J. Henkhe, E. A. Loew, William McClellan, Chester W. Rice, C. E. Skinner and R. D. Thomson.

Committee on Student Branches: C. W. Green, Chairman, Alexander Gray, C. Francis Harding, E. A. Loew, W. S. Rodman and C. F. Scott.

The special committee which had been appointed to consider the location for the 1917 Annual Convention, of

Digitized by Google

which Mr. J. Franklin Stevens was the Chairman, reported recommending that the Convention be held at the Homestead Hotel, Hot Springs, Virginia. The recommendation of the committee was approved, and it was voted to hold the Convention at the place indicated, during the week beginning June 25, 1917.

The report of the Board of Examiners at its meeting held on January 4 was read, and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners, 107 Students were ordered enrolled; 119 applicants were elected to the grade of Associate; 3 applicants were elected to the grade of Member, and 2 Associates were transferred to the grade of Member. The names of these applicants will be found elsewhere in this issue.

A considerable amount of other business was transacted by the Board, reference to which will be found in this and future issues of the PROCEEDINGS.

H. G. STOTT

Henry Gordon Stott, Past-president of the Institute, died at his home in New Rochelle, January 15th, 1917, after an illness of many months.

Mr. Stott was a native of the Orkney Islands, Scotland, where he was born in 1866, the son of the Rev. David and Elizabeth Jane (Dibblee) Stott. After a thorough grounding in the fundamentals at the hands of his father and elementary school instructors he was enrolled as a student at the Watson Collegiate School, Edinburgh. On leaving this institution he entered the College of Arts and Sciences at Glasgow, and began a course in mechanical engineering and electricity, graduating in 1885. In the previous year he had entered the employ of the Electric Illuminating Company of Glasgow. Shortly after graduating he was made assistant electrician on board the steamship *Minia*, belonging to the Anglo-American Telegraph Company. The next four and one-half years saw him engaged with those duties, during the course of which he saw much service in connection with repairs to the cable lines of that company. In this period he undertook a number of experiments that resulted in the introduction of improved methods of handling cable repairs. He was also identified with the duplexing of the United States Cable Company's main cable (2,750 knots), the longest duplex cable in the world.

In 1889 Mr. Stott was made assistant engineer of the Brush Electric Engineering Company's plant at Bournemouth, England. The following year he was offered a post by Hammond and Co. as assistant engineer in the construction of an underground cable and power plant at Madrid, Spain. He remained there until 1891, coming to the United States in that year to install an underground cable and conduit system for the Buffalo Light and Power Company (now the Buffalo General Electric Company). This work was completed with a degree of success that reflected very greatly to the credit of Mr. Stott. As a result he was named engineer of the company, and during the next ten years was one of the most active figures in the industrial progress of Buffalo. During this period he designed and executed some notable construction work, including a power plant on Wilkeson Street, Buffalo.

His efforts attracted wide attention and in 1901 he was appointed superintendent of motive power of the Interborough Rapid Transit Company, New York City, a position which he has filled with signal success. At the time he took up these duties the Interborough had not yet been organized, the company having the title of the Manhattan Railway Company. The post which Mr. Stott was called to had just been created, and it devolved upon him to organize the operating force, in connection with which he completed the Seventy-fourth Street power plant of the company, various substations and transmission lines.

Digitized by Google

When the Manhattan system was amalgamated with the Interborough in 1904 Mr. Stott was invited to retain his office with the new corporation. He accepted and immediately took over supervision of the construction of the power plant on Fifty-ninth Street. Since that time he has been constantly in charge of design, construction and operation of the power generating stations and the distributing system of the Interborough, which comprehends both the subway, elevated and surface lines of New York City.

The plans for the electric power system of the new subway lines have been developed under his supervision and the work has progressed so far and bears so strongly the stamp of his work that when completed it will be a monument to him.

Mr. Stott was a firm believer in co-operation among engineers, through the agency of engineering societies, and devoted much of his time and ability to the welfare and development of these professional organizations. He was elected president of the American Institute of Electrical Engineers for the term 1907-1908, having previously served as a member of the Board of Directors for three years. He was a vice-president of the American Society of Mechanical Engineers for the term 1912-1914, director of the American Society of Civil Engineers in 1911, and was vice-president and trustee of the United Engineering Society at the time of his death. Up to the last Mr. Stott was a recognized power in the Institute and was a member of the Standards Committee, the Public Policy Committee, the Committee on Development of Water Power, the United States National Committee of the International Electrotechnical Commission, the Power Stations Committee, the Committee on Economics of Electric Service, the Edison Medal Committee, and was one of the Institute's representatives on the Joint Committee on the Metric System.

As a result of his unusually wide experience and extended research Mr. Stott has been called upon often to contribute papers to the various engineering societies. He is especially well known for his minute analysis of engineering problems. Among the large number of papers which he has written on this subject are "The Conversion and Distribution of Received Currents," "Power Plant Economics", "Notes on the Cost of Power", "Steam Pipe Covering and its Relation to Station Economy", "Tests of a 15,000-Kilowatt Steam Engine Turbine Unit", "Power Plant Design and Operation", (a series) etc.

Mr. Stott was a remarkable figure in the engineering world because he was in the front rank of both electrical and mechanical engineers, because in both branches of the art, he was a master of theory and practise and because with these technical qualifications he combined a rare executive ability, a power of inspiring the confidence of his employees and of bringing out the best that was in the men who worked for him.

Mr. Stott's activities were not confined to engineering matters. He early became a citizen of the United States and served for five years in the 74th Regiment of the National Guard of New York State.

He was also an active member of the Protestant Episcopal Church, being a communicant of St. Paul's Church of New Rochelle, in the affairs of which he was deeply interested.

He was married July 22, 1894 to Miss Anna Mitchell, of Belfast, Ireland, who with their two children, a son and a daughter, survive him. The family home is located at New Rochelle, New York.

The Institute representatives at the funeral services on Wednesday evening, January 17, included Past Presidents John W. Lieb, C. O. Mailloux, Ralph D. Mershon, and L. B. Stillwell; Mr. Theo. Beran and Mr. Philip Torchio.

Digitized by Google

FLORIDA ENGINEERING SOCIETY

At a meeting held in Jacksonville, Florida, Dec. 22 and Dec. 23, 1916 with an attendance of about eighty, there was organized the Florida Engineering Society. The membership will include electrical, mechanical, civil and mining engineers, and naval architects.

The following officers were elected: President, L. D. Smoot, A. S. C. E.; Vice-presidents, W. P. Darwin, A. S. C. E.; and R. E. Chandler, A. S. M. E.; Secretary, J. R. Benton, A. I. E. E.; Treasurer, H. D. Mendenhall, A.S.C. E.

The first regular annual meeting will be held in Tampa, Florida, early in February.

A. I. E. E. MEETING IN PITTSBURGH JANUARY 12, 1917

The 328th meeting of the American Institute of Electrical Engineers was held Friday evening, January 12, 1917 in the Fort Pitt Hotel, Pittsburgh, Pa., under the auspices of the Pittsburgh Section and the Traction and Transportation Committee.

In addition to the evening technical session, there were during the day several committee meetings, as follows: The Standards Committee at 10 a.m. and the Membership Committee, the Traction and Transportation Committee and the Industrial Power Committee.

Under guides furnished by the local committee, various interesting inspection trips were taken to power stations, telephone exchanges and manufacturing plants in and about Pittsburgh. An informal dinner attended by about two hundred was held in the English Room of the Fort Pitt Hotel at 6:30 p.m.

After the tables had been cleared the technical session with about three hundred present was called to order by President Harold W. Buck at 8:15 p.m. President Buck presented Mr. R. E. Hellmund who gave a brief outline of his paper entitled "Regenerative Braking of Electric Vehicles". This paper called forth a spirited discussion by the following men: Robert Lundell, C. A. Adams, E. F. Alexanderson, A. J. Hall, R. E. Ferris, W. V. Turner, H. M. Hobart, F. R. Philips, C. E. Fortescue, K. A. Simmons, F. D. Newbury, W. B. Potter, N. W. Storer and R. E. Hellmund.

PAST SECTION MEETINGS

Baltimore.—December 15, 1916, Johns Hopkins University. Paper: "Heavy Electric Traction" by Clarence Renshaw. Attendance 42.

Boston.—January 9, 1917. Illustrated lecture by Dr. G. W. Pierce on "Gaseous Detectors for Amplifying Feeble Electric Currents". Dr. Pierce gave a demonstration of the working of the detector. Attendance 125.

Chicago.—November 25, 1916. Papers: (1) "Temperature Distribution in Electrical Machinery" by B. G. Lamme; (2) "Rational Temperature Guarantees for Large A-C. Generators" by F. D. Newbury. Attendance 150.

Cleveland.—December 15, 1916, Hotel Statler. Paper: "Speed Control of Induction Motors for Rolling Mill Drive" by Mr. Wright. Attendance 60.

Denver.—December 16, 1916, Denver Athletic Club. Paper: "The Application of Electric Drive to Mining Operations" by Franklin P. Wood. Attendance 31.

Detroit-Ann Arbor.—December 22, 1916. Address on "A-C. Circuit Fundamentals" by H. H. Higbee. Illustrated lecture on "Illumination as a Factor in Manufacturing Costs" by Geo. C. Keech. Attendance 35.

Ithaca.—December 15, 1916. Papers: (1) "Proposed Reserve Corps of Civilian Engineers for the U. S. Army" by Lieut. C. F. Williams, U. S. A.; (2) "Appraisals and Inventories of Electrical Properties" by A. B. Crandall and A. C. Woodward. Motion pictures entitled "Si Smith's Conviction". Attendance 50.

Los Angeles.—November 14, 1916,

Digitized by Google

Christophers. Annual Get-To-Gether Dinner. Attendance 98.

December 19, 1916, Chamber of Commerce. Paper: "Undamped Arc Oscillators for High-Power Radio Stations" by August Hund. Attendance 27.

Milwaukee.—December 20, 1916, Hotel Wisconsin. Illustrated address by Mr. J. W. Peterson on "Scientific Lubrication". Attendance 108.

January 6, 1917, Republican House. Address by Prof. I. N. Hollis, President of the A. S. M. E., on "The Place of the Engineer and the Engineering Society in Modern Life". Meetings under the auspices of local section of A. S. M. E. Attendance 65.

Minnesota.—December 18, 1916, Engineering Auditorium, University of Minnesota. Paper: "Transmission Economics and the Insulator Problem" by Lincoln Nissley. Paper was followed by a demonstration of high-voltage testing. Joint meeting of Minnesota Section and University of Minnesota Branch. Attendance 200.

Philadelphia.—November 13, 1916, Engineers Club. Illustrated address by Mr. A. O. Austin on "The Manufacture and Testing of High-Voltage Porcelains". Attendance 90.

November 23, 1916, Franklin Institute. Paper: "The Electric Strength of Air and Methods of Measuring High Voltage" by John B. Whitehead. Attendance 250.

December 11, 1916, Engineers Club. Paper: "What Electricity Has Done for Philadelphia" by E. J. Cattell. Motion pictures entitled "The King of the Rails". Attendance 80.

Pittsfield.—November 23, 1916, Hotel Wendell. Illustrated address by Mr. W. H. Bassett on "Copper and Its Alloys". Attendance 80

December 12, 1916, Hotel Wendell. Annual Dinner-Dance of the Pittsfield Section. Attendance 100.

December 14, 1916, Hotel Wendell. Paper: "Electric Transmission for Motor Cars" by W. B. Potter. Mr. Potter showed a number of stereopticon views to illustrate the paper. Attendance 150.

Rochester.—November 24, 1916, Rochester Engineering Society Rooms. Paper: "Electric Pyrometers" by Ralph C. Schwarz. Attendance 29.

Spokane.—December 15, 1916, Millwood. Paper: "The Application of Electricity in the Manufacture of Paper" by A. W. Fisher. Following presentation of the paper an inspection was made of the plant of the Inland Empire Paper Company. Attendance 60.

Toledo.—December 22, 1916, Toledo Art Museum. Ilustrated lecture by Mr. John B. Taylor on "Color Photography with Microscope and Stereoscope". Attendance 65.

January 3, 1917, Toledo Commerce Club. Motion picture entitled "The King of the Rails". Election of officers as follows—chairman, W. E. Richards; vice-chairman, George E. Kirk; secretary-treasurer, Max Neuber. Attendance 23.

Toronto.—December 15, 1916, Engineers Club. Addresses by Capt. Mathison R. C. E., and Lieut. Armer, on "The Work of the Engineer at the Front". Illustrated address by Mr. G. H. Hill on "Railway Electrification". Attendance 61.

Washington.—December 12, 1916, Cosmos Club. Paper: "Good Illumination and Its Satisfactory Production" by J. S. Romig. Attendance 40.

PAST BRANCH MEETINGS

Armour Institute.—December 21, 1916. Paper: "The Engineer's Personal Equipment". Attendance 34

Brooklyn Polytechnic Institute.—November 17, 1916, Mailloux Library. Lecture entitled "The Telephone Girl". Attendance 59.

December 15, 1916, Mailloux Library. Paper: "The Proper Metering of the Energy of a Central Station", by F. V. Magalhaes. Election of officers as follows—chairman, Paul G. Wehle; first vice-chairman, Henry J. Goss; second vice-chairman, Lester M. Gill; secre-

Digitized by Google

tary, Robert Davie; treasurer, Frank E. Canavaciol. Attendance 35.

Bucknell University.—December 13, 1916. Ilustrated lecture on "The Panama Canal; Its Construction and Operation".

Carnegie Institute of Technology.—December 13, 1916, Machinery Hall. Symposium on "Railway Electrification" by Messrs. A. L. Morley, E. G. Peterson, W. W. Wolfe and L. V. Bohannon. Attendance 20.

University of Cincinnati.—December 13, 1916. Lecture by Mr. C. R. Underhill on "Electromagnets". Attendance 42.

Clarkson College.—November 22, 1916. Papers: (1) "Rational Temperature Guarantees for Large A-C. Generators" by F. D. Newbury; (2) "Temperature Distribution in Electrical Machinery" by B. G. Lamme. Attendance 16.

December 13, 1916. Address by Dr. J. P. Brooks on "My Experiences as an Engineer". Attendance 20.

December 20, 1916. Illustrated lecture on "The Apprenticeship System at Westinghouse Elec. and Mfg. Co." Attendance 17.

January 4, 1917. Paper: Boilers and Boiler Stokers—Their Care and Operation" by B. R. Robinson. Attendance 16.

Colorado State Agricultural College.—December 18, 1916, Electrical Hall. Illustrated lecture by Prof. F. G. Persons on "The Electron Theory as an Explanation of Magnetic Phenomena". Motion picture entitled "The King of the Rails". Attendance 18.

Lafayette College.—December 16, 1916. Papers: (1) "Thermit and Thermit Welding"; (2) "Methods of Electrical Welding"; (3) " Manufacture of Mazda Lamps"; (4) "Gas Filled Lamps for Street Lighting". Attendance 19.

January 5, 1917. Papers: (1) "The Pennsylvania Water Power Company's Plant at Holtwood, Pa."; (2) "Bakelite and Its Uses". Attendance 20.

January 13, 1917. Papers: (1) "Light Reflecting Values of Paints"; (2) "Water Power Developments". Attendance 16.

University of Missouri.—December 18, 1916, Engineering Building. Paper: "Empirical Curves" by E. R. Hedrick. Attendance 25.

University of Nebraska.—January 10, 1917, Electrical Engineering Building. Addresses by Messrs. E. M. Kadlecek and H. B. Whitfield on "the Application of Electricity to Automobiles". Election of officers as follows—chairman, O. J. Ferguson; corresponding secretary, F. C. Holtz; student chairman, H. B. Whitfield; student secretary, I. B. Starr; treasurer, Fred Garrison. Attendance 14.

North Carolina College of Agricultural and Mechanical Arts.—January 10, 1917. Mr. G. C. Cox spoke on "Wireless Theory". Mr. R. M. Hooper demonstrated the lighting power of a small electromagnet, and showed the process of electroplating. Attendance 14.

Ohio Northern University.—January 10, 1917, Dukes Memorial. Addresses by Messrs. Parson and Ferlic on "Overhead and Underground Contact Systems for Electric Railways".

Ohio State University.—January 5, 1917, Physics Building. Addresses by Mr. C. F. Kettering on "The Relation of the Engineer to Industry". Attendance 400.

Oregon Agricultural College.—December 14, 1916. Paper: "Lake Spaulding Power Development" by G. J. A. Hooper. Attendance 19.

Purdue University.—December 8, 1916, Electrical Building. Paper: "Electromagnets and Electromagnetic Mechanism" by C. R. Underhill. Attendance 60.

January 9, 1917, Electrical Building. Papers: (1) "Industrial Control" by L. D. Rowell; (2) "Construction and Operation of Electric Headlights" by E. R. Warren. Attendance 46.

University of Texas.—November 15, 1916. Election of officers as follows—chairman, J. W. Ramsay; secretary-treasurer J. A. Correll; executive com-

Digitized by Google

mittee, W. C. Blair, W. H. Harrison, and W. E. Buckner. Attendance 17.

December 13, 1916. Address by Prof. J. M. Bryant on "The Development of Electrical Transportation". Motion picture "The King of the Rails". Attendance 172.

January 12, 1917. Papers: (1) "Electric Locomotives" by L. B. Walker; (2) "Historical Development of Collecting Devices for Electric Locomotives" by W. A. Darter. Attendance 24.

Agricultural and Mechanical College of Texas.—December 15, 1916. Address on "The Schenectady Works of the General Electric Company" by Prof. W. G. James. Attendance 28.

University of Washington.—December 13, 1916, Forestry Hall. Papers: (1) "The General Characteristics of Substation Operation" by Adolph Huelsdonk; (2) "Experiences of a Substation Operator" by A. S. Grenland. Attendance 19.

Worcester Polytechnic Institute.—January 5, 1917, Electrical Engineering Building. Illustrated lecture "From Ore to Finished National Tubing" by H. T. Miller. Joint meeting with local branches of A. S. M. E. and civil engineering society. Attendance 150.

MEMBERS ELECTED JANUARY 12, 1917

JOHNSON, HARLEY ALDEN, Master Mechanic, Metropolitan West Side Elevated Ry. Co., Northwestern Elevated R. R. Co., Chicago & Oak Park Elevated R. R. Co., Chicago, Ill.

KNOWLTON, ARCHER E., Asst. Professor of Physics; Power & Illumination Expert for Public Utilities Commission; res., 37 Brownell Ave., Hartford, Conn.

TRANSFERRED TO THE GRADE OF MEMBER JANUARY 12, 1917

The following Associates were transferred to the grade of Member of the Institute at the meeting of the Board of Directors on January 12, 1917.

JONES, REGINALD L., Transmission Engineer, Western Electric Co., New York, N. Y.

LENT, WILMAR F., Electrical Engineer, Cutler-Hammer Mfg. Co., New York, N. Y.

RECOMMENDED FOR TRANSFER, JANUARY 4, 1917

The Board of Examiners, at its regular monthly meeting on January 4, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

KNIGHT, GEORGE LAWRENCE, Designing Engineer, Edison Electric Illuminating Co. of Brooklyn, Brooklyn, N. Y.

PIERCE, ALBERT EDWIN, Vice-President and General Manager, Wisconsin-Minnesota Power & Light Co., Eau Claire, Wis.

TESLA, NIKOLA, Inventor, New York, N. Y.

VON KROGH, KARL KONORO, Consulting Electrical Engineer, Nissen & von Krogh, Christiania, Norway.

To Grade of Member

LINDSTROM, GUSTAV, Chief Engineer and Secretary, Electric Products Co., Cleveland, O.

MORROW, LESTER WILLIAM WALLACE, Associate Professor of Electrical Engineering, University of Oklahoma, Norman, Okla.

WOOLFENDEN, H. L., District Manager, Allis-Chalmers Mfg. Co., Denver, Colo.

ASSOCIATES ELECTED JANUARY 12, 1917

*ALDRICK, LOUIS COOK, Electrician, New England Westinghouse Co., E. Springfield; res., 68 Monmouth St., Springfield, Mass.

Digitized by Google

*ATWELL, CLARENCE ALLEN, Instructor in General Engineering Drawing, University of Illinois; res., 610 W. Oregon St., Urbana, Ill.

BATTIN, WILLIAM INGRAM, Engineer, Southern Div., Northern Indiana Gas & Electric Co.; res., 1220 W. Washington St., Ft. Wayne, Ind.

*BAXTER, HAROLD CALHOUN, Chairman, Engineering Dept., Pennsylvania Railroad Co.; res., 915 So. 48th St., Philadelphia, Pa.

BAXTER, HUBERT KATHAN, Electrical Squad Boss, Drafting Dept., Stone & Webster Engineering Corp., Boston; res., 1340 Commonwealth Ave., Allston, Mass.

BEARY, DONALD BRADFORD, Lieutenant, U. S. Navy, Furnald Hall, Columbia University, New York, N. Y.

*BEAVER, GEORGE LOVELL, Testing Dept., General Electric Co.; res., 230 Union St., Schenectady, N. Y.

*BELLVILLE, JAMES R., Foreman, Service Station, Wagner Electric Mfg. Co., St. Louis; res., 116 Central Ave., Clayton, Mo.

BENNINGER, MARSHALL P., Material Foreman, Electrical Division, Panama Canal, Balboa, Canal Zone.

*BESSESEN, BEN B., Mechanical Draftsman, Brinkley Supply Co.; res., 4123 11th Ave. N. E., Seattle, Wash.

BIRELEY, JESSE L., Meter Engineer, General Electric Co.; res., 327 W. Butler St., Fort Wayne, Ind.

*BRESSLER, HARPER V., Inspector on Electrification, Gibbs & Hill; res., 4825 Walton Ave., Philadelphia, Pa.

BROCKWAY, REUBEN MILLER, Industrial Control Engg. Dept., General Electric Co.; res., 26 Eagle St., Schenectady, N. Y.

*BROWN, CLAUDE CHARLES, Asst. Boiler Room Engineer, Station "A", Pacific Gas & Electric Co., San Francisco; res., Berkeley, Cal.

BURNHAM, ROY R., Electrical Engineer, Monks & Johnson, 78 Devonshire St., Boston; res., 32 Dudley St., Medford, Mass.

*BURNS, THOMAS STEPHEN, Asst. to Supt. of Distribution, Elmira Water, Light & Railroad Co., Elmira, N. Y.

BUTLER, PAUL HOUSTON, Manager, New York Office, Pittsburgh Transformer Co., 30 Church St.; res., 305 W. 45th St., New York, N. Y.

CAMERON, GORDON, Engineer, Oil Circuit Breaker Div., Condit Electrical Mfg. Co., South Boston; res., 45 Sachem St., Wollaston, Mass.

CLARKE, EUGENE CALDWELL, Assistant Engineer, Aerial Line Dept., Philadelphia Electric Co., 1000 Chestnut St.; res., 5120 N. 15th St. W., Philadelphia, Pa.

*COLE, HORACE LEE, Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 403 Hay St., Wilkinsburg, Pa.

CORNELL, ROBERT LESLIE, General Manager, Kentucky River Power Co., Hazard, Ky.

CURTIS, RALPH L., Electrical Engineer, Fisher Body Corp.; res., 111 Spruce St., Detroit, Mich.

*DACE, FRED EDWIN, Power Plant and Substation Design, Elec. Engg. Dept., Goodyear Tire & Rubber Co.; res., 45 Spruce St., Akron, O.

DE CAMP, RAY EDWARD, Electrical Engineer, Industrial Control Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 204 West St., Wilkinsburg, Pa.

DEL PUGLIA, ANTONIO, Engineer, Societa Elettrotecnica Galileo Ferraris; res., Piazza Costello 4, Milano, Italy.

DHOOGE, VICTOR C., Electrical Engineer, Detroit Screw Works; res., 56 Mitchell Ave., Detroit, Mich.

*DIEHL, GEORGE SANDY, Electrician, West Penn Power Co., Pittsburgh; res., 310 Locust St., Butler, Pa.

DIXON, HARRY JAMES, Switchboard Operator, Substation No. 2, Hudson & Manhattan R. R. Co.; res., 3057 Bailey Ave., New York, N. Y.

d'OLIVEIRA, EDMOND, Head of Technical Staff, Cie. Liuha Circular, Cie. Trilhos Centrals; res., Ladeira de Barre No. 11, Bahia, Brazil, S. A.

Digitized by Google

DUNLAP, HARRY BOYD, Oil Flotation Operator, Nevada Consolidated Copper Co., McGill, Nev.

*EDISON, OSKAR EDWIN, Operating Dept., Commonwealth Edison Co., Station No. 2; res., 1504 E. 53rd St., Chicago, Ill.

*FADEN, JAMES LEATHERBEE, French & Hubbard, 88 Pearl St., Boston; res., 18 Pleasant St., Waltham, Mass.

*FAIRBANKS, FRANK BATES, Advertising Man, Department of Publicity, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

FOLEY, J. W. BEASLEY, Assistant Manager, Marconi Wireless Telegraph Co.; res., 130 Lakeshore Drive, Port Arthur, Tex.

*GANSCHOW, LLOYD WHEATON, Electrolysis Engineer, Plant Dept., Western Union Telegraph Co., Cleveland; res., 42 13th Ave., Columbus, O.

GILMAN, WILLIAM F., Utility Manager, Central Illinois Public Service Co., Beardstown, Ill.

*GOETZENBERGER, RALPH LEON, Power & Mining Engineering Dept., General Electric Co.; res., 244 Union St., Schenectady, N. Y.

*GOOCH, EVERETT P., Railway Engineering Div., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 612 Hill Ave., Wilkinsburg, Pa.

HANSEN, KLAUS LOBECK, Designing Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 310 Trenton Ave., Wilkinsburg, Pa.

HAROLD, WILLIAM HENRY, Electrician; res., 347 Grove, Walla Walla, Wash.

HAUSER, WILLIAM S., Electrician, Public Service Corp.; res., 313 S. 11th St., Newark, N. J.

*HAUSMANN, VALENTINE FRANK, Cadet Engineer, Philadelphia Electric Co.; res., Central Branch, Y. M. C. A., Philadelphia, Pa.

HEIDENREICH, ALLAN HARLAN, Electrical Engineer, Firestone Tire & Rubber Co., Akron, O.

HOFFMANN, JACOB J., In charge of Tool Room, Vilter Manufacturing Co.; res., 495 Murray Ave., Milwaukee, Wis.

HOGLUND, GUSTAV E., Assistant Engineer, Demand Meters, General Electric Co.; res., 743 Walnut St., Fort Wayne, Ind.

*HOLMES, WILLIAM MOWRY, Estimator of Transmission Line Construction, Pacific Light & Power Corp., Los Angeles; res., Alhambra, Cal.

HOPPIN, GILBERT HAND, Electrical Engineer, Hazard Manufacturing Co.; res., 165 West River St., Wilkes-Barre, Pa.

HOSEGOOD, PHILIP EDGAR, Consulting Engineering Laboratory, General Electric Co.; res., 417 Union St., Schenectady, N. Y.

*HUDSON, WILLIS FENTON, Testman, General Electric Co.; res., 53 Washington Ave., Schenectady, N. Y.

HULING, JOHN EDWARD, JR., Tester, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 704 Johnston St., Wilkinsburg, Pa.

*HUXLEY, ROY DESMOND, Transmission & Protection Engg. Dept., American Tel. & Tel. Co., New York, N. Y.; res., 69 Prospect St., East Orange, N. J.

*IMES, OLIVER STAPP, Distribution Engineering Dept., T. M. E. R. & L. Co.; res., 279 25th St., Milwaukee, Wis.

JOHNSON, STANLEY FRANCIS, Electrical Engineer, American Steel and Wire Co.; res., 28 Rockdale St., Greendale, Worcester, Mass.

JOHNSON, THOMAS DANIEL, Meter Dept., Alabama Power Co.; res., 2216 12th Ave. N., Birmingham, Ala.

*KENT, PHILIP JAMES, Director of Studebaker Technical School, Studebaker Corp.; res., 1297 John R. St., Detroit, Mich.

KESTER, HAROLD JACKSON, Service Dept., Westinghouse Electric & Mfg. Co.; res., 164 W. Huron St., Buffalo, N. Y.

*KILBY, HUBERT ST. CLAIR, Engineer, Madison Co. Light & Power Co. St. Louis Electric Terminal Ry. Co., St. Louis Electric Bridge Co., St. Louis, Mo.

Digitized by Google

*KIRK, JOHN BARNES, Engineer, American Telephone & Telegraph Co., 195 Broadway, New York, N. Y.; res., E. Orange, N. J.

*KRANZ, HERMANN ERNEST, Instructor in Electrical Engineering, University of Wisconsin; res., 122 N. Orchard St., Madison, Wis.

*KRUG, FREDERICK, In charge of Electrical equipment, and student, New Mexico State School of Mines, Secorro, N. M.

LANNING, JOHN G., Assistant Engineer, Ashcroft Mfg. Co.; res., 905 Lafayette St., Bridgeport, Conn.

*LAUE, GILBERT ERIC, Engineer, Cutler-Hammer Mfg. Co.; res., 1000½ 16th St., Milwaukee, Wis.

*LEAVITT, ARTHUR R., Electrical Draftsman, Carnegie Steel Co.; res., 28 N. 2nd St., Duquesne, Pa.

LININGER, CLARENCE R., Chicago Manager, Pittsburgh Transformer Co., 724 Harris Trust Bldg.; res., 649 Arlington Place, Chicago, Ill.

*LITTLE, CLAUDIUS B., Assistant to Chief Electrical Engineer, Franklin Railway Supply Co., New York, N. Y.; res., 1313 14th St. N. W., Washington, D. C.

*MAILHOUSE, ROBERT JACOB, Stone & Webster Engineering Corp., Youngstown, O.; res., 105 Elm St., New Haven, Conn.

*MARCY, CHARLES GOODELL, Student Engineer, General Electric Co., Schenectady, N. Y.; res., Montesano, Wash.

MARCUM, THOMAS EDWARD, Operator, Anaconda Copper Mining Co.; res., 272 13th St., Great Falls, Mont.

*MARKHAM, ARTHUR J., Engineering Dept., American Telephone & Telegraph Co., New York, N. Y.; res., 186 Summit Ave., Summit, N. J.

MARVIN, HARRY B., Testing Dept., General Electric Co.; res., 115 Nott Terrace, Schenectady, N. Y.

*MCLENNAN, JOHN CHARLES EARLE, Cadet Engineer, Philadelphia Electric Co.; res., 3706 Locust St., Philadelphia, Pa.

*MCNABB, GEORGE CORBIN, Draughtsman and Electrical Engineer, Caulk Machine Co.; res., 515 City Line, Oak Lane, Philadelphia, Pa.

*MILLER, SERENO GLASSELL, Head of Engineering Dept., New Bedford Textile School, 1191 Purchase St.; res., 490 Union St., New Bedford, Mass.

*MITTENTHAL, NORMAN JEROME, Student Engineer, Testing Dept., General Electric Co.; res., 702 Campbell Ave., Schenectady, N. Y.

*MOON, FLOYD L., Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 618 Kelly Ave., Wilkinsburg, Pa.

MUEHLEMAN, HENRY JACOB, Operating Dept., Hydro-Electric Power Commission; res., 93 Beatrice St., Toronto, Ont.

*NASH, JOHN F., Power Transformer Test, General Electric Co.; res., 19 Myrtle St., Pittsfield, Mass.

NIKIFOROFF, BASIL, Engineer, Central Station Dept., Russian General Electric Co., Petrograd, Russia.

*O'HAGAN, BERNARD EUGENE, Engineer, Power Estimating Dept., Union Switch & Signal Co., Swissvale; res., 711 Berkshire Ave., Pittsburgh, Pa.

*ORDÓNEZ, BENITO RENÉ, Research Fellow, Engineering Experiment Station, University of Illinois, 114 Transportation Bldg., Urbana, Ill.

PAINTEN, ALAN MOWATT, Electrician in charge, Purity Distilling Co., East Cambridge; res., 115 W. Elm Ave., Wollaston, Mass.

*PHELPS, HENRY EDISON, Assistant in Electrical Engineering, Purdue University; res., 348 State St., West Lafayette, Ind.

POLLOCK, JOHN DONALD, Engineer, Pacific Telephone & Telegraph Co., 1103 Telephone Bldg., Portland, Ore.

*POLSTER, MILTON A., Chief Testman, Consolidated Gas, Electric Light & Power Co.; res., 2001 Boone St., Baltimore, Md.

Digitized by Google

RANSOM, CARLETON AUSTIN, Student, Stevens Institute of Technology; res., 532 River St., Hoboken, N. J.

*RASCH, GUSTAV ALEXANDER, Engineering Inspector, Chesapeake & Potomac Telephone Co., Baltimore; res., 105 St. John's Road, Roland Park, Md.

RINGSTROM, IVAN G., Engineering Assistant, Department of Public Utilities, City of St. Paul; res., 1196 De Sota St., St. Paul, Minn.

*RITTER, RALPH WILLIAM, Electric Storage Battery Co.; res., 2950 N. 12th St., Philadelphia, Pa.

ROBERTS, HENRY G., Electrician, Canadian Consolidated Mining Co., Trail, B. C.

*ROGERS, CLAYTON TAYLOR, Salesman, Westinghouse Electric & Mfg. Co., Union Bldg.; res., 2 Hubbard Court, Charleston, W. Va.

SCHLESINGER, IRVIN S., Electrical Engineer, Pennsylvania Shipbuilding Co., Gloucester, N. J.; res., 41 S. 50th St., Philadelphia, Pa.

SCLATER, R. H., Insurance Electrical Inspector, South-Eastern Underwriters Association; res., Majestic Hotel, Atlanta, Ga.

SELDEN, GEORGE KEARSLEY, Engineer, Southern Bell Telephone & Telegraph Co., 57½ S. Pryor St.; res., 30 Inman Circle, Atlanta, Ga.

*SEWELL, GEORGE LAWRENCE, Draftsman, Signal Engineer's Office, Illinois Central Railroad Co.; res., 6425 Kenwood Ave., Chicago, Ill.

*SMALL, JOSEPH CHANDLER MORRIS, Inspector, Canadian Niagara Power Co., Niagara Falls, Ont.; res., 124 Third St., Niagara Falls, N. Y.

*SMITH, ERWIN G., Chief Electrician, Central Aguirre Co., Central Aguirre, Porto Rico.

*SMITH, HAROLD LEONARD, Designing Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 104 Colonial Apts. Wilkinsburg, Pa.

*SMITH, WALTER HERBERT, Con rol Engineer, Railway Div., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

SNYDER, EDWARD BEDELL, Sales Agent, Ohio Brass Co.; res., 283 Park Ave. West, Mansfield, O.

*SODERSTROM, CARL A., Switchboard Installer, Mountain States Tel. & Tel. Co.; res., 380 S. Pearl St., Denver, Colo.

SPRAGUE, CLAUDE W., Operator, B. & M. Smelter; res., 1621 8th Ave. N., Great Falls, Mont.

*SPURGEON, JOSEPH HARRISON, Special Assistant to Supt. of Power Dept., E. I. du Pont de Nemours & Co., City Point, Va.

*STACK, ALVAN HUEY, District Superintendent, Ohio Service Co., Dennison, Ohio.

STEGE, FRED H., JR., Assistant to District Foreman, Public Service Electric Co., East Rutherford; res., 20 Waltbery Ave., Ridgewood, N. J.

*STEVENS, HAROLD WAIT, Engineer, Cutler-Hammer Mfg Co.; res., 137 25th St., Milwaukee, Wis.

*STREET, LOCKWOOD NORTHCOTT, Assistant Purchasing Agent, Long Island Lighting Co ; res., 146 W. 80th St., New York, N. Y.

*STRECKER, GEORGE M., Tester, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 417 Center St., Wilkinsburg, Pa.

*SWEITZER, LEONARD EDWARD, Proposition Engineer, Transformer Dept., General Electric Co.; res., 189 First St., Pittsfield, Mass.

TAYLOR, DONALD WILLIAM, Cadet Engineer, Public Service Electric Co., Newark, N. J.; res., 2051 Fifth Ave., New York, N. Y.

THOMPSON, JAMES EDGAR, Automatic Telegraph Engineer, Western Union Telegraph Co.; res., 408 East Cary St., Richmond, Va.

TRONE, SOLOMON, Representative of the Russian General Electric Co., Petrograd, Russia.

*WELKER, JAMES ARTHUR, Electrician, West Penn Power Co., Butler; res., 633 So. Center St., Grove City, Pa.

Digitized by Google

*WENTWORTH, HERBERT HIRAM, Railway Engineering, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 512 Franklin Ave., Wilkinsburg, Pa.

WEST, CARL ORRIN, Engineering Dept., Home Telephone and Telegraph Co.; res., 1009 E. 52nd St., Los Angeles, Cal.

WHITING, BRUCE INGALLS, 610 Forest Ave., Evanston, Ill.

*WILLIAMS, EDWARD EUGENE, Student Engineer, General Electric Co.; res., 28 Mynderse St., Schenectady, N. Y.

WOLFF, ADOLPH FRANK, Substation, Operator, Spokane and Inland Empire Railway Co.; res., 410 W. 3rd Ave., Spokane, Wash.

WORDEN, MARSHALL W., Factory Engineer, General Electric Co.; res., 625 W. Wayne St., Fort Wayne, Ind.

ZEHR, VRATISLAV ADOLPH, Draftsman, Switchboard Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 820 Wood St., Wilkinsburg, Pa.

Total 119.

*Former enrolled Students.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before February 29, 1917.

Alger, P. L., Cambridge Mass.
Allcutt, C. T., E. Pittsburgh, Pa.
Armstrong, A. A., Watertown, S. D.
Asher, L., Preston, Idaho
Atwood, F. R., Springfield, Ill.
Bailey, R. S., Salt Lake City, Utah
Batcheller, B. C. (Member), New York, N. Y.
Baugh, C. E., San Francisco, Cal.
Beatty, L. B., Philadelphia, Pa.
Beyer, W. W., Philadelphia, Pa.
Biesgen, A., Milwaukee, Wis.
Billingsley, C. H., Galena, Ill.
Blackwood, W. C., Long Island City, N. Y.
Bothwell, J. H., Youngstown, O.
Brate, C. F., Pittsburgh, Pa.
Brown, H. B., Edmonton, Alta.
Brown, R. E., Philadelphia, Pa.
Burggraf, K. H., Euclid, O.
Burnap, R. S. Cambridge, Mass.
Calvert, H., Philadelphia, Pa.
Cann, J.O.G. (Member),Glace Bay,N.S.
Cantlin, A. H. S., Allentown, Pa.
Coe, E. H., Denver, Colo.
Connell, B. R., Schenectady, N. Y.
Costello, W. H., Milwaukee, Wis.
Cox, J. W., Durham, N. C.
Cozad, W. F., Denver, Colo.
Cuerdon, T. J., Cohoes, N. Y.
De Muth, F. A., Chicago, Ill.
Dougherty, J. J., Pittsburgh, Pa.
Drew, W. W., Chicago, Ill.
DuMond, J. W. M., Schenectady, N. Y.
Du Vall, W. C., Philadelphia, Pa.
Ensweiler, E. J., Milwaukee, Wis.
Easley, C. B., Boston, Mass.
Fernandes, J. M., Rio de Janeiro, Brazil.
Finn, J. R. (Member), Milwaukee, Wis.
Fleming, A. K., New Brunswick, N. J.
Fleming, D. B., Toronto, Ont.
Friede, H., Toledo, O.
Ford, W. A., Rome, Ga.
Foster, J. T., Newark, N. J.
Foster, W., Philadelphia, Pa.
Fourtellott, A., Erie, Pa.
Fox, E. A., Charleston, S. C.
Funk, R. J., Pittsburgh, Pa.
Gaskell, S. A., Toronto, Ont.
Gauss, W. F., Pittsburgh, Pa.
Genor, A. C. Pittsburgh, Pa.
Gibbony, A. P., E. Pittsburgh, Pa.
Girdlestone, C. F. New York, N. Y.
Goldschmidt, A. L., Malta, Mont.
Goldthwaite, G. E., New York, N. Y.
Gomez, L. G., Denver, Colo.
Gorman, E. R., Groton, Conn.
Grah, M. E., Toledo, O.
Harvey, J. W., Orono, Me.
Heath, L. A., New York, N. Y.
Heuer, R. H., Milwaukee, Wis.
Holland, W. E., Dallas, Tex.

Digitized by Google

Holzberger, G. R., San Francisco, Cal.
Howard, R. B., Philadelphia, Pa.
Howe, W. M., Lynn, Mass.
Huey, C., New York, N. Y.
Jeffers, G. L., E. Pittsburgh, Pa.
Jersey, C. C., Washington, D. C.
Johnson, A. F., Salt Lake City, Utah
Johnston, W. D., Pittsburgh, Pa.
Joyner, A. H. W., Toronto, Ont.
Kazda, C. B., Chicago, Ill.
Keeler, F. S., New York, N. Y.
Kelley, C. A., Preston, Idaho
Kerr, H. H., Warren, O.
Knipfer, F. C., Schenectady, N. Y.
Kurtz, W. O., New York, N. Y.
Lagerstrom, D. R., Schenectady, N. Y.
Laros, R. K., Allentown, Pa.
Larviviere, A., Quebec, Que.
Lee, H. R., Springfield, Ill.
Leech, R. W., E. Pittsburgh, Pa.
Leibold, C. A., Reading, Pa.
Lester, J. R., Ensley, Ala.
Lockyer, R. H. N., Trail, B. C.
Logan, R. S., Montreal, Que.
Lowell, H. G. (Member), Boston, Mass
Lupinski, H. H., New York, N. Y.
Lyndon, L. (Fellow), New York, N. Y.
Madden, M. F., Grand Canyon, Ariz.
Mann, A. W. (Member), Mattoon, Ill.
Marr, G. M., Brooklyn, N. Y.
Mathews, F. P., Dryden, Ont.
Maxwell, G. S., Schenectady, N. Y.
McKee, G. S., Wellsburg, W. Va.
Menon, K. C. (Member), Delhi, India
Meyer, W. E., (Member), Newark, N.J.
Mickler, C. F., Atlanta, Ga.
Millar, E. A., Jr., New York, N. Y.
Miller, W. H., Erie, Pa.
Moore, E. E., Toronto, Ont.
Moyer, M. S., Chicago, Ill.
Munninghoff, A., Milwaukee, Wis.
Nabeshima, U., Brookline, Mass.
Nakagawa, T., Kyoto, Japan
Neely, F.L. (Member), Wilmington, Del.
Oberschmidt, F. H., Milwaukee, Wis.
Orwig, C. E., Pittsburgh, Pa.
Owen, F. B., Ft. Wayne, Ind.
Owen, W. B., Jr., Wilkes Barre, Pa.
Panton, H. D., Raliegh, N. C.
Payton, M. J., Ft. Wayne, Ind.
Pierce, T. B., Bluefield, W. Va.
Plass, C. W., Philadelphia, Pa.
Potter, F. R., St. Louis, Mo.
Publow, C. F., Toronto, Ont.
Ralston, F. C., Ogontz, Pa.
Raynor, K. M., S. Bethlehem, Pa.
Rees, L. du B., E. Pittsburgh, Pa.
Riley, L.G. (Member), E. Pittsburgh, Pa.
Robertson, A. S., Toronto, Ont.
Ross, J. H., Freeport, Tex.
Russell, E. G., Chicago, Ill.
Russell, F. J., Milwaukee, Wis.
Russell, W., New York, N. Y.
Rust, E. P., Philadelphia, Pa.
Samuelson, J. A., Russell, Kans.
Sanford, J. H., Philadelphia, Pa.
Schneider, F. W., New York, N. Y.
Schwarze, F., Milwaukee, Wis.
Scutari, C., New York, N. Y.
Seabrook, W. C., Philadelphia, Pa.
Seibert, W. J., Erie, Pa.
Shakin, V., New York, N. Y.
Shute, E. R. (Member), NewYork, N.Y.
Smoot, W. S., Cleveland, O.
Snider, G. E., Toledo, O.
Stearn, F. A., New York, N. Y.
Stephenson, G. B., Milwaukee, Wis.
Stewart, F. J. T. (Member), New York, N. Y.
Stewart, H. C., Pittsfield, Mass.
Stoddart, H. G., Newark, N. J.
Stoetzel, D., Jr., Schenectady, N. Y.
Story, E. C., Boston, Mass.
Swan, S. B. (Member), Providence, R. I
Swartz, C. A., Pittsburgh, Pa.
Taussig, W. A., St. Louis, Mo.
Tetelman, L. L., New York, N. Y.
Thayer, C. S., Massena, N. Y.
Thompson, C. M., Jr., Philadelphia, Pa.
Thompson, G. G. (Member), Milwaukee, Wis.
Thompson, H. L., New York, N. Y.
Thorn, C. S., Philadelphia, Pa.
Thornburg, C. A., Kingsport, Tenn.
Tonge, J. L., Providence, R. I.
Townsend, C. P., Atlanta, Ga.
Townsend, F. P., Milwaukee, Wis.
Trueblood, H. M., Philadelphia, Pa.
Vautrot, L. R., Milwaukee, Wis.
Wade, H. N., Milwaukee, Wis.
Webber, L. H., Harrison, N. J.
Webster, J. C., Cleveland, O.
Welsh, R. W., Philadelphia, Pa.
Whitbeck, W. L., Denver, Colo.
Wightman, J. W., Cincinnati, O.
Williams, S. S., Roanoke, Va.

Digitized by Google

Wood, R. A., E. Pittsburgh, Pa.
Wood, W. M., Philadelphia, Pa.
Yokura, M., New York, N. Y.
Zimmerman, A. W., Ft. Wayne, Ind.
Zimmerman, W. J., Philadelphia, Pa.
Zoller, M. L., Sacramento, Cal.
Zornig, H. H., Watertown, Mass.
Total 171

STUDENTS ENROLLED JANUARY 12, 1917

8581 Bostwick, G. L., Univ. of Wis.
8582 Paret, H. W., Jr., Yale Univ.
8583 Juliber, M., Brooklyn Poly. Inst.
8584 Anderson, M. D., Univ. of Mich.
8585 Austin, E. R., Univ. of Mich.
8586 Bartelme, E. A., Univ. of Mich.
8587 Cosgrove, M. G., Univ. of Mich.
8588 Cowing, G. R., Univ of Mich.
8589 Cutting, M. B., Univ of Mich.
8590 Fishleigh, C. T., Univ. of Mich.
8591 Hill, C., Univ. of Mich.
8592 Kennedy, L. W., Univ. of Mich.
8593 Kishlar, L. M., Univ. of Mich.
8594 Lueck, H. E., Univ. of Mich.
8595 Milburn, L. R., Univ. of Mich.
8596 Newbold, A. T., Univ of Mich.
8597 Norman, E. E., Univ. of Mich.
8598 Osborn, B. K., Univ. of Mich.
8599 Roosenraad, A. C., Univ. of Mich
8600 Rowan, W. H., Univ. of Mich.
8601 Warner, W. W., Univ. of Mich.
8602 Zwickey, C. E., Univ. of Mich.
8603 Margenau, M. L., Univ. of Wis.
8604 Puente, M. de J., Syracuse Univ.
8605 Nash, L. B., Univ. of Wis.
8606 Richardson, H. R., Univ. of Ill.
8607 Evans, D. G., Univ. of Ill.
8608 Huber, A. J., Univ. of Ill.
8609 Short, P. B., Univ. of Colo.
8610 Young, B. U., Univ. of Colo.
8611 Ekrem, T. C., Univ. of Colo.
8612 Smith, H. M. R., Univ. of Colo.
8613 Eastman, H. L., Univ. of Colo.
8614 Leroy, V. E., Univ. of Colo.
8615 Coit, N. H., Univ. of Colo.
8616 Hinkle, A. E., Univ. of Colo.
8617 Clymer, C. C., Univ. of Colo.
8618 Gittings, W. N., Univ. of Colo.
8619 Auslebrook, W. J., Univ. of Colo.
8620 Merritt, R. W., Univ. of Colo.
8621 McCrum, D. S., Univ. of Colo.
8622 Tashima, Y., Univ. of Colo.
8623 Schloss, C. M., Univ. of Colo.
8624 Hardenbrook, M.E., Univ. of Colo.
8625 Kelly, J. R., Mass. Inst. Tech.
8626 Chase, L. H., Yale Univ.
8627 Curtis, E. M., W. Va. Univ.
8628 Martin, B. H., Univ. of Wis.
8629 Lathrop, W. F., Ore. Agri. Coll.
8630 Kitzman, W. L., Univ. of Wis.
8631 Waite, H. E., Stanford Univ.
8632 Rohrback, D. W., Stanford Univ.
8633 Wilson, G. W., Stanford Univ.
8634 Royden, G. T., Stanford Univ.
8635 Miller, F. R., Stanford Univ.
8636 Likely, R. D., Stanford Univ.
8637 Hampton, F. G., Stanford Univ.
8638 Norton J. E., Wentworth Inst.
8639 Irwin, F. H., Univ. of Minn.
8640 Dressler, A., N. Y. Elec. Sch.
8641 Lim, F. Y., Kans. State Agri. Coll.
8642 Ham, F. M., Lehigh Univ.
8643 Davie, R., Brooklyn Poly. Inst.
8644 Kehrn, G. C., Lehigh Univ.
8645 McDowell, H. E., Lehigh Univ.
8646 Einstein, R., Carnegie Inst. Tech.
8647 Wagner, E. G., Univ. of Missouri
8648 Harburg, R. C., Univ. of Wis.
8649 Woolhy, F. H., Univ. of Colo.
8650 Hoffman, R. A., Univ. of Colo.
8651 Reed, S., Univ. of Colo.
8652 Shimeall, H. R., Univ. of Colo.
8653 Page, H. A., Univ. of Colo.
8654 Milroy, J., Univ. of Colo.
8655 Wynn, H. A., Univ. of Colo.
8656 Aslanides, D. J., Univ. of Mich.
8657 Brunson, L. W., Univ. of Mich.
8658 Collins, W. H., Univ. of Mich.
8659 Klein, J., Univ. of Mich.
8660 Koonsman, H. D., Univ. of Mich.
8661 Loucks, F., Univ. of Mich.
8662 Rowe, A. O., Univ. of Mich.
8663 West, D. C., Univ. of Mich.
8664 Green, L., Univ. of Manitoba
8665 Foster, M. E., Norwich Univ.
8666 Rosenberg, L. H., Armour Inst. of Tech.
8667 Benjamin, A. S., Armour Inst. of Tech.
8668 Gray, H. E., Univ. of Wash.
8669 Appuhn, W. E. F., Brooklyn Poly. Inst.
8670 Dowd, D. E., Highland Park Coll.

Digitized by Google

8671 Dickey, R.F., Highland Park Coll.
8672 Parsons, F.W., Ohio Northern Univ.
8673 Compton, R. O., Cornell Univ.
8674 Hegel, G. W., Univ. of Mich.
8675 Mason, C. W., Bucknell Univ.
8676 Wilder, W. S., Univ. of Wis.
8677 McKensie, D.H., Penna. State Coll.
8678 Vogdes, F. B., Armour Inst. Tech.
8679 Lombardo, R. P., Lewis Inst.
8680 Walker, R. M., Univ. of Mo.
8681 Blank, A. C., Case Sch. App. Sci.
8682 Rowand, A. M., Ohio Nor. Univ.
8683 Boyum, I. L., Univ. of Minn.
8684 Storz, J. F., Ga. Sch. Tech.
8685 Smith, W. W., Mass. Inst. Tech.
8686 Zaun, J., 3rd, Univ. of Penna.
8687 Gerken, H. A., N. Y. Elec. Sch.
Total 107

PERSONAL

MR. A. W. K. BILLINGS formerly managing director and vice-president of the Ebro Irrigation and Power Company, Ltd., Barcelona, Spain, has opened an office as consulting engineer at 115 Broadway, New York. Previous to his work in Spain Mr. Billings spent two years in Pittsburgh and ten years in Cuba on electric railway and power plant construction and for two years was engineering manager of J. G. White & Co., Inc.

MR. W. A. HOLLAND, JR., after eleven years with the General Electric Co. at Schenectady, principally in the Switchboard Engineering Dept., has resigned to take up the teaching of electrical engineering in Mackenzie College, Sao Paulo, Brazil,

MR. W. E. SKINNER, consulting engineer, of 415 Plymouth Bldg., Minneapolis, Minn., on account of increased business has been compelled to move into larger quarters in the same building.

MR. HALBERT P. HILL is a member of the newly incorporated firm of Ophuls, Hill & McCreery, consulting engineers, 112 West 42nd St., New York. This new firm will specialize on mechanical and electrical engineering, ice and refrigeration, and the design and construction of special electrical apparatus.

Digitized by Google

EMPLOYMENT BULLETIN

Vacancies.—The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN. The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES.

V-199. Wanted: Two electrical draftsmen, experienced in substation and generating station switchboard work. Permanent positions; salary $25. Location, Brooklyn, N. Y.

V-201. Consulting Engineer with important practice can offer an unusually good opportunity to one or two young men, recently graduated from first-class engineering school. Good personality and correct use of English are as essential as technical training. Moderate salary, with increase as earned. Complete record of training in applicant's handwriting, requested in first communication. Location, Cincinnati.

V-202. Wanted: Engineer to act as Chief Engineer in large central station power house in an Atlantic Seaboard city. Must be qualified to take charge of 80,000 kw. plant and experienced in handling Curtis turbines, jet and surface condensers, and Taylor stokers. Applicant must have experience in large central station plants. State age, experience and salary expected. If employed, give name of company and reason for changing. All replies strictly confidential.

V-203. Appraisal Engineers and Assistants. Permanent positions in engineering organization of public utility holding company for several engineers experienced in this character of work. Give particulars as to general qualifications, particularly undertakings with which previously associated, nature of positions held, and salaries expected. Work will start as soon as a force can be organized.

V-204. Several positions in engineering organization of New York public utility holding company, for engineers experienced in design of steam and hydroelectric stations, and transmission and distribution systems. Replies should give particulars of training and experience, and salaries expected.

V-205. Chief Draftsman or Assistant Engineer to handle primarily steam piping, $175 per mo; also two draftsmen for mechanical work of same nature, $120-$130 per mo.

MEN AVAILABLE.

646. Electrical Engineer, technical graduate, age 38, married; sixteen years' domestic and foreign experience in engineering, construction and operation of railway, lighting and power stations. Overhead and underground distribution systems. Familiar with specifications, contracts, estimates and reports, etc. Available after February 1.

647. Sales Engineer, technical graduate, E. E. and M. E., six years' shop and test experience, two years' executive and sales experience. Can get results either by direct selling or correspondence. Certified figures shown relative to effectiveness in present connection. Married; prefers to remain in Detroit, but will consider good resident proposition anywhere.

648. Ambitious young man of proven executive, business and engineering ability, wishes to enter larger central station or related field. Graduate of combination electrical engineering and business administration course of well-known Eastern university. Would make excellent executive in a progressive concern with a promising future to offer.

649. Development Engineer, technical man, B. S. and E. E., age 29, desires connection with manufacturer of electrical products or capital for same, desiring the development of new lines of manufacture. Especially familiar with magnetos and the patent situation of that field. Possesses practical ability and sufficient scientific inclina-

Digitized by Google

tion to be original and thorough in solution of problems.

650. Railroad power or central station work; technical graduate (Cornell), with six years' experience in power department of electrified steam road; inspection, testing, operation of power plants and substations. Also service plant supplying steam and hot water heat, electric power, compressed air, refrigeration to hotels, office buildings; cost and rate work.

651. Load Dispatcher, technical graduate; five years' mechanical experience. Open for engagement on short notice. Has been with present employers about three years. Will consider position as load dispatcher or maintenance engineer. Salary $1500.

652. Mem. A. I. E. E., with twenty years' experience in design, construction and operation of steam and hydro-electric plants, underground and overhead distribution; high tension transmission systems; desires position where experience and executive ability can be demonstrated.

653. Electrical Engineer, technical graduate, age 30, married, wishes responsible position as manager or assistant manager new business department light and power company. Eight years' experience general electric test and sales dept., steam-electric power plant construction, operation, rates, industrial power engineering. Employed but wishes larger field. Minimum salary $1800.

654. Electrical Engineer, technical education, several years' varied electrical engineering experience. Familiar with design, manufacture and application of a-c. and d-c. power machinery to industrial work. Able to combine engineering theory with broad practical experience and sound common sense to successful solution of electrical engineering problems. Age 32; married.

655. Graduate Electrical Engineer, age 36, sixteen years' experience in central station testing, operation, construction and distribution; eight years in responsible executive direction. Desire position requiring my combination of experience. Am married, a teetotaler, and am now employed.

656. Electrical Engineer, age 36, married. Technical graduate; completed apprenticeship course W. E. & M. Co.; Sales Dept. Allis-Chalmers-Bullock Co.: Electrical Inspector in charge, for Fire Underwriters in Western state, nine years. Special correspondent for Western electrical publication. Desires to make change to another engineering position, sales work, or would consider sales agency for Pacific Coast.

657. Young married man, technically educated, seven and half years' experience in meter and instrument work; testing; trouble, and complaint work on switchboards, control apparatus, motors, generators; and appraisal. Desires position as superintendent meter and testing dept., distribution, or stations and substations, or chief electrician.

658. Electrical Engineer, with fifteen years' experience in manufacture, testing and installation of electrical machinery; steam turbines and engines; sub and main station electrical design; desires position in charge of design or construction of stations for a central station company, or as electrical engineer for a large industrial concern. Possesses initiative and resourcefulness.

659. Electrical Engineer, technical graduate, desires change. Seven years' experience in telephone engineering and in manufacture and testing of power apparatus. Experienced in handling men. Age 30, married.

660. Assistant Electrical Engineer, 32, familiar with material inspections, supplies, parts, nomenclature, classification and management of stores. Fifteen years' field construction and office experience, domestic and foreign.

661. Technical Graduate, seven years' experience in electric railway and power station, design, testing and operation. One year apprentice with G. E. Co. At present employed but desires position with greater opportunity for advancement.

662. Graduate Electrical Engineer, age 36, who has advanced from fireman and engineer to the position of general superintendent of a company with a gross revenue of $2,000,000, desires an executive operating position with a large holding company.

663. Electrical engineering graduate, (1916) desires position with consulting engineering firm, offering good prospects for the future, and opportunity for research or construction. Location in the south or west preferred. At present employed on General Electric test.

664. Technical Graduate. Thirteen years' experience in design, construction and operation of power stations, substations, transmission and distribution systems for railway and power systems. Estimating, specifications, cost data, drafting, concrete, steel and general engineering office work. Desires to

Digitized by Google

connect permanently with railway, lighting or manufacturing company as engineer on construction or operation.

665. Electrical Engineer, ten years' experience in electric power generation, distribution, design, construction and operation. Specialized on high and low tension a-c. work, including railroad electrification. Proven ability handling men. College graduate. Now employed in responsible operating position. Desires change with better outlook. Correspondence solicited.

666. Electrical Engineer, desires position as assistant, resident or designing engineer. College graduate, eight years electrical manufacturing companies; five years' constructing and operating. Particularly qualified as designing or assistant electrical engineer power stations, transmission, industrial control, electrical rolling mills, specifications and technical correspondence. English, 6'—0", 150 pounds, total abstainer.

667. Electrical Engineer, age 34, with technical training and employed at present, desires to change his position. Experience—ten years in construction work; four years in motor designing dept. of large manufacturing company. Thoroughly familiar with design of multi-speed polyphase motors.

668. Technical Graduate, age 26, with five years' electrical experience in operating depts., both East and West, desires a position with a power company.

669. Electrical Engineer, several years with largest electrical manufacturers here and abroad, experience in testing, drafting, design mill and mine equipments, railway work and export sales, seeks engagement where hard work and ability secures rapid advance. Specialty advanced physics. Four languages. Prefers position with consulting engineer as assistant.

670. Electrician, fifteen years' experience in operation and repair of electrical machinery. Experienced in telephone work and all kinds of wiring. Past seven years as chief electrician in large industrial plant. Married; strictly temperate. Correspondence solicited.

671. If you want a good trustworthy man who can give you the best results in charge of construction work, or as Assistant Electrical Engineer, would be pleased to send an outline of my past experience. Will consider temporary employment; salary reasonable.

672. Electrical Engineer, age 29, broad technical and business training, executive ability, two years in charge of design and manufacture of small electrical apparatus; desires an opening in a manufacturing company with an opportunity of acquiring an interest in the firm.

673. Electrical Engineer, age 35, graduate from well-known Eastern technical institute, long experience in testing and general commercial engineering work; specialized on electrical equipment for hoists and rolling mills, just returned from four years' experience abroad, available immediately. Commencing salary a secondary consideration where there is a real opportunity for advancement.

674. Graduate Electrical Engineer, with ten years' experience in operating, construction and commercial work, with large central station companies, desires position of manager or superintendent of electric property in town of 10,000 or over. Am 33 and married. At present employed. Will consider anything in the States or Alaska.

675. Graduate Electrical Engineer, ten years' practical experience in design and manufacture of a-c. and d-c. motors. Experience in the application of motors to crane service. Interview solicited.

676. Graduate Electrical Engineer, (1908). Eight years' experience. Can competently handle installation and operation of hydroelectric plants; a-c. and d-c. motors, generators and switchboards. At present employed; desires position in Western state, as superintendent of construction or operation. Will make my own opportunity for advancement.

677. Industrial Plant Engineer. Technical graduate with ten years' experience on motors, lighting, testing equipments, electric welding, plating, switchboards and power stations. Specialized on switchboard design five years. Desires position of responsibility with industrial plant or public service company.

678. Practical Construction or maintenance electrical engineer with business training Alexander Hamilton Institute; age 35; desires responsible position on operating or managing staff in hydroelectric, steel or carbide industry.

679. Electrical Engineer, age 35, of thirteen years' broad business and engineering experience on small and moderate size motors and generators and control apparatus, on design,

Digitized by Google

manufacture and application. Mem. A. I. E. E. Salary $3500.

680. Public Utilities or Electrical Contracting. Electrical engineer experienced in illumination, industrial and residential, light and power installations and estimating, power applications, maintenance work, salesmanship, for past fifteen years, desires position where executive ability and efficient methods are required. Los Angeles district and Portland, (Ore) district only considered.

ACCESSIONS TO LIBRARY.

This list includes books which have been presented to the library of the A. I. E. E. and the U. E. S. during the past month, not including periodicals and other exchanges.

Electrical Insulating Properties of Transformer Oil. By T. Hirobe, W. Ogawa and S. Kubo. (Abstract of Report No. 25, of the 3d Section). Tokyo, 1916. (Gift of Electrotechnical Laboratory Imperial Department of Communication.)

New York Electric Railway Association. Annual Report, 34th, 1916. Schenectady, 1916. (Gift of Association.)

UNITED ENGINEERING SOCIETY

American Railway Association. Car Shortage Statistics. New York, 1916. (Gift of Asssociation.)

Gold Mining in Korea. By Edwin W. Mills. (Royal Asiatic Society Trans. Vol. VII, pt. I.) v.p. 1916. (Gift of Edwin W. Mills.)

Handbook of Westinghouse Watthour Meters. (Publication No. 5150.) (Gift of Westinghouse Electric & Manufacturing Co.)

International Engineering Congress. Transactions vols. 1-11 and Index. San Francisco, 1915. (Gift of International Engineering Congress.)

New York State Museum. Report of the Director, 1915. Albany, 1916. (Gift of University of the State of New York.)

Numerical Classification of Photography. Rochester, 1916. (Gift of Eastman Kodak Company.)

Pittsfield (Mass.) Ordinance Amending Building Ordinance. (Gift of City Clerk.)

Some Properties of Vibrating Telephone Diaphragms. By A. E. Kennelly and H. O. Taylor. (Reprinted from Proceedings of American Philosophical Society, vol. IV, 1916.) (Gift of Massachusetts Institute of Technology, Electrical Engineering Department, Bulletin No. 11, April 1916.)

What is Preparedness? By H. L. Gantt. (Reprint from Engineering Magazine, Sept. 1916.) (Gift of Frederick W. Taylor Co-Operators.)

(GIFT OF CLEMENS HERSCHEL.)

Atlanta, Birmingham and Atlantic Railroad Company. Valuation of the property of. Before the Interstate CommerceCommission.

Federal Valuation of the Railroads in the United States. Circular communication to Chairmen of Valuation Committees. Dec. 15, 1916.

Federal Valuation of the Railroads in the United States. Statement prepared by Thomas W. Hulme, of the developments in connection with Federal valuation as of December 30, 1916.

Kansas City Southern Railway Company. Tentative Valuation by Interstate Commerce Commission, Nov. 20, 1916.

——Report of the cost of reproduction new and cost of reproduction less depreciation. Engineering.

——Summary and explanatory text of the land report.

New Orleans, Texas and Mexico Railroad Company. Tentative Valuation by Interstate Commerce Commission, Nov. 21, 1916.

Texas Midland Railroad Company. Valuation of the property of. Before the Interstate Commerce Commission.

(GIFT OF F. R. HUTTON.)

Boiler Code of the American Society of Mechanical Engineers. By S. F. Jeter. (Address before the National Association of Cotton Manufacturers, Apr. 26, 1916.)

Boiler Safety Orders. Issued by the Industrial Accident Commission of the State of California. Effective Jan. 1, 1917. California, 1916.

Legislation to Govern Construction of Boilers. (Editorial from Dallas News, June 22, 1916.)

Ohio Boiler Inspection Law, 1916.

Ohio Boiler Inspectors' Convention. Report of the Proceedings, 1916.

Plea for Uniform Boiler Specifications. By T. E. Durban. (Paper read before the American Boiler Manufacturers' Association, Sept. 1913.)

Proposed Uniform Boiler Code. (Louisiana Planter.)

Uniform Boiler Laws. By T. E. Durban. (Address before the Texas Cotton Seed Crushers Association, May 29, 1916.)

Uniform Specifications for Boilers. By T. E. Durban. (Address before 2d Pennsylvania Industrial Welfare and Efficiency Conference Nov. 19, 1914.)

(GIFT OF ALBERT F. GANZ.)

Effect of Electrolysis on Engineering Structures. (Paper read at meeting International Engineering Congress, 1915.)

Electrolytic Corrosion of Iron by Direct Current in Street Soil. (Paper presented at 29th Annual Convention, Amer. Inst. Electrical Engrs., June 25, 1912.)

Electrolysis from Stray Electric Currents. (Before Amer. Water Works Association, June 6, 1912) and New England Association of Gas Engineers, Feb. 19, 1913.)

Report. Investigation for Stray Electric Currents in the City of Winnipeg and in Adjoining Municipalities to H. A. Robson. 1915.

Report on Electrolysis Conditions in Springfield, Ohio. 1914.

Report on Insulated Return Feeder System for Mitigating Electrolysis, installed by the United Railways Company of St. Louis, Mo., in the Ann Ave. Substation District. May, 1914.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917) **SECRETARY.**
GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY.
RALPH W. POPE

LIBRARIAN.
W. P. CUTTER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to February 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.
N. A. Carle, George A. Hamilton,
John H. Finney, William McClellan,
Bancroft Gherardi, J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.
N. A. Carle, Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.
Frederick Bedell, F. W. Peek, Jr.
Philander Betts, F. L. Rhodes,
J. G. De Remer, D. W. Roper,
H. A. Hornor, Harris J. Ryan,
Edward P. Hyde, T. H. Schoepf
L. E. Imlay, Charles P. Steinmetz,
E. H. Martindale, N. W. Storer,
Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
Frederick Bedell, L. T. Robinson,
M. G. Lloyd, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
Engineers' Club, 32 West 40th Street, New York.
E. B. Katte, W. I. Slichter,
F. L. Rhodes, Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
J. G. De Remer, A. M. Schoen,
Paul M. Lincoln, J. H. Tracy,
and the chairmen of all Institute Sections, *ex-officio.*

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.
G. M. Baker W. G. Chace,
S. H. Blake, H. W. Flashman,
E. H. Martindale.
and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
E. A. Carolan, A. M. Hunt,
John J. Carty, William McClellan,
Fredk. Darlington, H. H. Porter,
Gano Dunn, C. S. Ruffner,
John B. Pisken, A. M. Schoen,
L. B. Stillwell,

COMMITTEE ON DEVELOPMENT OF WATER POWER.

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.
F. O. Blackwell, Nicholas S. Hill, Jr.,
Francis Blossom, E. A. Lof,
Gano Dunn, W. V. N. Powelson,
L. B. Stillwell,

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Harvard University, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, H. M. Hobart,
Frederick Bedell, H. D. James.
Joseph Bijur, P. Junkersfeld,
L. F. Blume, A. E. Kennelly,
James Burke, G. L. Knight,
G. A. Burnham, A. S. McAllister,
N. A. Carle, W. M. McConahey,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
W. A. Del Mar, C. E. Skinner,
E. J. Edwards, A. J. Slade,
H. W. Fisher, N. W. Storer,
R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTRO-TECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, M. I. Pupin,
B. A. Behrend, E. B. Rosa,
Louis Bell, Charles F. Scott,
James Burke, Clayton H. Sharp,
John J. Carty, Samuel Sheldon,
Gano Dunn, C. E. Skinner,
H. M. Hobart, Charles P. Steinmetz,
John W. Lieb, Elihu Thomson,
R. B. Owens, Philip Torchio.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, Charles A. Terry,
John F. Kelly, B. F. Wood.

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.

A. E. Kennelly, Chairman, Robert T. Lozier,
S. G. McMeen.

Term expires July 31, 1918.

H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.

Charles F. Brush N. W. Storer
C. C. Chesney,

Term expires July 31, 1920.

Carl Hering Harris J. Ryan
H. G. Stott.

Term expires July 31, 1921.

W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.

B. A. Behrend, Paul M. Lincoln,
William McClellan.

Term expires July 31, 1918.

C. A. Adams, Harold Pender,
C. E. Skinner.

Ex-Officio.

H. W. Buck, President,
George A. Hamilton, Treasurer,
P. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to February 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
100 Broadway, New York.

J. M. Drabelle,	S. A. Moss,
C. C. Egbert,	R. J. S. Pigott,
W. S. Gorsuch,	Cecil Poole,
John Harisberger,	E. F. Scattergood,
A. H. Kruesi,	F. A. Scheffler,
Paul M. Lincoln,	W. R. Thompson,
Wynn Meredith,	Philip Torchio,
L. E. Moultrop,	H. L. Wallau,

B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,	P. M. Lincoln,
M. T. Crawford,	W. E. Mitchell,
E. E. P. Creighton,	G. J. Newton,
H. H. Dewey,	L. C. Nicholson,
P. M. Downing,	W. D. Peaslee,
H. W. Fisher,	Stefaan Piek,
P. A. Gaby,	C. S. Ruffner,
W. T. Goddard,	H. J. Ryan,
O. A. Havill,	F. D. Sampson,
R. P. Hayward,	H. R. Shedd,
J. P. Jollyman,	Julian C. Smith,

P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman,
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,	P. J. Kearny,
A. H. Babcock,	William McClellan,
Reinier Beeuwkes,	John Murphy,
E. J. Blair,	W. B. Potter,
L. P. Crecelius,	E. D. Priest,
J. V. B. Duer,	Charles H. Quinn,
George Gibbs,	Clarence Renshaw,
W. J. Harvie,	A. S. Richey,
Hugh Hazelton,	Charles F. Scott,
E. B. Katte,	John B. Taylor,

H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,	G. A. Johnstone,
J. H. Davis,	C. A. Kelsey,
James Dixon,	C. L. Kennedy,
A. M. Dudley,	Charles D. Knight,
Herbert B. Dwight,	A. H. Lawton,
P. W. Ells,	A. M. MacCutcheon,
J. E. Fries,	A. G. Pierce,
F. R. Fishback,	James M. Smith,
R. H. Goodwillie,	H. Weichsel,
A. L. Hadley,	J. B. Wiard,

R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,	Richard C. Powell,
C. E. Clewell,	E. B. Rosa,
J. R. Cravath,	W. D'A. Ryan,
T. S. Perkins,	Clayton H. Sharp,

W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,	A. H. Kruesi,
W. H. Blood, Jr.,	William McClellan,
Fred A. Bryan,	Norman C. McPherson,
C. L. Cory,	Allard Smith,
Harry Clifford Eddy,	W. G. Vincent,
W. B. Jackson,	George W. Whittemore,

G. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman
Room 500, 72 W. Adams St., Chicago, Ill.

L. L. Elden,	A. A. Meyer,
G. Faccioli,	L. C. Nicholson,
V. E. Goodwin,	N. L. Pollard,
E. M. Hewlett,	S. D. Sprong,
Paul M. Lincoln,	Philip Torchio,

H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,	F. G. Liljenroth,
F. A. J. Fitzgerald,	Eugene F. Roeber,
A. F. Ganz,	J. A. Seede,
F. A. Lidbury,	R. Tschentscher,

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,	E. B. Rosa,
A. C. Crehore,	Harris J. Ryan,
G. Faccioli,	Clayton H. Sharp,
C. L. Fortescue,	C. P. Steinmetz,
W. S. Franklin,	P. H. Thomas,
A. E. Kennelly,	J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
195 Broadway, New York.

E. F. W. Alexanderson,	Kempster B. Miller,
R. E. Chetwood,	H. Mouradian,
M. M. Davis,	W. O. Pennell,
C. L. Fortescue,	Allard Smith,
H. M. Friendly,	John S. Stone,
F. B. Jewett,	John B. Taylor,
S. M. Kintner,	J. L. Wayne, 3rd,
Wm. Maver, Jr.,	G. M. Yorke.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.
D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,	Guy Hill,
M. W. Day,	O. P. Loomis,
G. E. Edgar,	G. A. Pierce, Jr.,
W. L. R. Emmet,	H. M. Southgate,
W. R. Furlong,	E. A. Sperry,
H. L. Hibbard,	Wilfred Sykes,

F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,	L. C. Ilsley,
Frank H. Armstrong,	R. L. Kingsland,
Graham Bright,	Charles Legrand,
W. A. Chandler,	Charles M. Means,
F. J. Duffy,	K. A. Pauly,

H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,	A. G. Pierce,
F. B. Crosby,	J. C. Reed,
E. Friedlaender,	R. Tschentscher,
E. S. Jefferies,	Brent Wiley,
D. M. Petty,	R. B. Williamson

J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman.

Alexander Gray,	William McClellan,
E. J. Henkhe,	Chester W. Rice,
E. A. Loew,	C. E. Skinner,

R. D. Thomson.

Digitized by Google

SPECIAL COMMITTEES.

Revised to February 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N..Y
F. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman;
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. F. Scott.

PROPOSED RESERVE CORPS OF ENGINEERS.

Bion J. Arnold, Chairman,
105 South La Salle Street, Chicago, Ill.
John Harisberger, A. M. Schoen,
Ralph D. Mershon, Charles W. Stone.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

Ralph D. Mershon, Paul M. Lincoln,
C. O. Mailloux, John J. Carty,

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Harold Pender, Edward D. Adams,
W. I. Slichter, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan,
John J. Carty.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON JOINT NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly,

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand.
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.
A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa

Digitized by Google

LIST OF SECTIONS

Revised to February 1, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg. Atlanta,Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St.,Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, American Electrical Heater Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	Walter A. Black, 3042 Graceland Ave., Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	Gordon Campbell	M. B. Carroll, G. E. Co., West Lynn, Mass.
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7, '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18. '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, Pacific Power and Light Co., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	Lucien Buck, 1416 Lake Avenue, Rochester N. Y.
St. Louis.....Jan. 14, '03	A.McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woobridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	E. T. J. Brandon	Wills Maclachlan, 910 Excelsior Life Building, Toronto, Ont.
Urbana.....Nov. 25, '02	I. W. Fisk.	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D.C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. T. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazier, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	N. J. Rehman	E. C. Hageman, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Marc Holzer	A. C. Maynard, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College..Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.. .....June 25, '14	D. Nankervis	L. J. Corbett, Univ. of Idaho, Moscow, Idaho.
Iowa State College.....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	R H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	N. M. Foster	G. M. Bowman, 1517 New Hampshire, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky. Lexington, Ky.
Lafayette College.....Apr. 5, '12	Samuel McC. Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels.
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of....May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr., and Mech. Arts.....Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
Norwich University.....June 28, '16		
Ohio Northern Univ.....Feb. 9, '12	W. C. Bedell	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University....Dec. 20, '02	H. D. Bender	L. W. Birch, 138 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	H. M. Richards	R. E. Heffner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	G. Geracimos	August Heine, State College, Pa.
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst...Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col.Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	C. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash, State Col. of.....Dec. 13, '07	C. H. Worthen	C. J. Melrose, State Col. of Wash., Pullman, Wash.
Washington Univ. .....Feb. 6, '04	Charles A. Lieber	R. W. Macdonald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ.....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 57.

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI MARCH, 1917 Number 3

A. I. E. E. MEETING IN CHICAGO MARCH 9, 1917

The 330th meeting of the American Institute of Electrical Engineers will be held in Chicago, Ill., March 9, 1917. The official headquarters of the Institute during the meeting will be in the Hotel Sherman, Clark and Randolph Streets, where the various committee meetings and the technical session will be held.

The registration office in the Hotel Sherman will be open at 8:30 a.m. and members and guests are requested to register promptly. The Western Society of Engineers 1735 Monadnock Block has extended the privilege of its rooms to members and guests of the A. I. E. E. during the meeting.

The morning and afternoon will be devoted to various committee meetings, to a number of inspection trips which are scheduled below, and to the Board of Directors meeting.

At 6:30 p.m. an informal dinner will be served in the Crystal Room of the Hotel Sherman to members and guests in attendance.

The technical session will be held in the Louis XVI room of the Hotel Sherman at 8:00 p.m. The general subject of the meeting will be *Methods of Relay Protection* and two papers will be presented; one by Mr. Philip Torchio, of the New York Edison Co. and one by Mr. R. F. Schuchardt, of the Commonwealth Edison Co. of Chicago.

A number of interesting inspection trips has been arranged for Saturday morning and afternoon following the meeting, as scheduled below.

PROGRAM

Friday Morning

Committee meetings as specified in notices to committee members.

Inspection trips as scheduled below.

Friday Afternoon

Board of Directors Luncheon, University Club, 1 p.m.

Committee meetings as specified in notices to committee members.

Inspection trips as scheduled below.

Friday Evening

Informal dinner in Crystal Room, 6:30 p.m.

Technical Session

8:00 p.m.

Relays for High-Tension Lines, by Philip Torchio.

The use of definite and inverse-time-limit, selective-ground, reverse-power and differential relays for the protection of feeders, tie lines, ring systems, generators and transformers as instanced by current practise.

The Protective Relay Equipment on the System of the Commonwealth Edison Company, by R. F. Schuchardt.

The arrangement and setting of relays on large inter-connected systems: Generators are equipped with balanced relays; lines with induction-type inverse-time-limit relays; some of the

Digitized by Google

uni-directional type, and balanced relays; substations have the usual equipment of overload relays, speed-limit devices, etc.; and outgoing feeders the instantaneous type of relays.

Saturday

Inspection trips as scheduled below.

INSPECTION TRIPS

Friday, March 9th, 1917

MORNING

Commonwealth-Edison Substations

Plymouth Place. 15 minutes walk from Hotel Sherman. Combined Edison and railway converter substation with 6,000 kw. total capacity in converters and a large railway storage battery and booster.

Market Street. 5 minutes walk from Hotel Sherman. 2,000 kw. vertical converter and storage battery and booster on railway system.

Franklin Street. 10 minutes walk from Hotel Sherman. 10,000 kw. total converter capacity.

Sherman Street. 10 minutes walk from Hotel Sherman. 5,500 kw. converter capacity. Stand-by storage battery.

Friday, March 9th, 1917

AFTERNOON

Illinois Steel Company, Electric Furnace, South Chicago.

North West Station of Commonwealth-Edison Company.

Western Electric Company—Hawthorne.

Special train on elevated. Luncheon at plant. Leave Fifth Ave. Terminal 12:30 p.m.

Saturday, March 10, 1917

MORNING

Bell Telephone Exchanges. Lake View, Rogers Park, Belmont, Stewart Hyde Park. Chicago has the most up-to-date telephone system in the world.

Electric Steel Company. Snyder Furnace. Automatic Sub-Station.

Special train on Elgin and Belvidere. A railway automatic substation that starts, synchronizes and stops in accordance with power demand. (See PROCEEDINGS for September 1915.)

Fisk Street Station of Commonwealth-Edison Company.

Saturday, March 10, 1917

AFTERNOON

Stock Yards

Chicago Railways Company.

Western Ave. Substation.

A modern railway converter substation, 12,000-kw. capacity.

Kedzie Ave. Car House.

321-car capacity. A modern layout with necessary equipment.

The West Shops.

One of the most modern and efficient electric railway car shops in the country, showing many features of interest.

More complete information in regard to the above trips can be obtained at the Registration office. Guides will be furnished for all trips.

INFORMAL DINNER

An informal table d' hote dinner will be served to members and guests in the Crystal Room in the Hotel Sherman at 6:30 p.m.

Price $1.50 per cover.

Dinner tickets should be purchased at the registration office as early as possible.

HOTEL SHERMAN

All correspondence in regard to hotel reservations should be addressed to the hotel management.

Hotel rates on the European plan are as follows:

Single Rooms with bath

$2.00, 2.50, 3.00, 3.50, 4.00 and 5.00.

Double Rooms with bath

$3.00, 3.50, 4.00, 4.50, 5.00 and 6.00

Digitized by Google

A. I. E. E. MEETING AT SCHENECTADY APRIL 13, 1917

The 331st meeting of the American Institute of Electrical Engineers will be held in Schenectady; N. Y., April 13, 1917. The Institute headquarters during the meeting will be in the Edison Club, 60 Washington Avenue. The meeting will be under the auspices of the Standards Committee and the general subject of the meeting will be "Temperature Corrections." A paper on this subject will be presented by Mr. V. M. Montsinger of the General Electric Co. In addition to Mr. Montsinger's paper, four other papers bearing on allied subjects will be taken up for discussion. These are as follows: *Temperature Distribution in Electrical Machinery*, by B. G. Lamme, *Rational Temperature Guarantees for Large A-C. Generators*, by F. D. Newbury, *Internal Temperatures of A-C. Generators*, by Ralph Kelly, and *Electrical Machinery Tests and Specifications Based on Modern Standards*, by H. M. Hobart.

The papers by Messrs. Lamme and Newbury were published in the November, 1916, PROCEEDINGS, the paper by Mr. Kelly in the February, 1917. PROCEEDINGS, and the paper by Mr, Hobart appears in this issue.

A. I. E. E. ANNUAL CONVENTION JUNE 26-29, 1917

The Annual Convention of the Institute will be held at Hot Springs, Va., covering the four day period, June 26-29, 1917. The Homestead Hotel has been selected as the headquarters for the convention.

The Meetings and Papers Committee has tentatively decided on five technical sessions. The convention will open on the afternoon of Tuesday, June 26, with President H. W. Buck's address followed by the reports of the various technical committees. The two sessions on Wednesday, the 27th, will be under the auspices of the Transmission and Distribution Committee. The morning will be devoted to the subject of "high-tension cables" and three papers on this subject will be presented, as follows: *Certain Insulation Characteristics of High-Voltage Cables*, by W. S. Clark and G. B. Shanklin; *Problems in Operation and Maintenance of Underground Cables*, by John L. Harper; *Fundamentals of High-Tension Cable Joints*, by D. W. Roper. The afternoon session will be devoted to high-tension insulators", and four papers will be delivered, as follows: *The Insulator Situation*, by W. D. Peasley; *Porosity of Electrical Porcelain*, by H. J. Ryan; *Expansion Effects as a Cause of Deterioration in Suspension-Type Insulators*, by J. A. Brundige; *Present Practise in the Design and Manufacture of High-Voltage Insulators*, by A. O. Austin. The morning of Thursday, June 28, has been designated as the Mining Session and the following papers will be presented: *Forms of Power Best Suited for the Various Loads Encountered in the Operation of Bituminous Coal Mines*, by R. L. Kingsland; *Test of a Large Mine Hoist*, by R. S. Sage. The fifth and last technical session will be held Friday morning, June 29. This will be a Railway Session and the papers to be delivered will be announced later.

The Entertainment Committee has under consideration the usual program of sports with some novel and interesting features. The complete program will be announced in a future issue.

COMING SECTION MEETINGS

Boston.—March 6, 1917. Subject: "Electric Transmission for Motor Cars. Speaker: W. B. Potter.

Detroit-Ann Arbor.—March 23, 1917. Subject: " Direct-Current Motors. Speaker: Prof. B. F. Bailey.

Fort Wayne.—March 8, 1917. Motion Picture entitled "King of the Rails".

Spokane.—March 15, 1917. Subject: Utilization of Electricity.

Toronto.—March.—March 16, 1917. Subject: "The Construction and Prac-

Digitized by Google

tise of Underground Cables. Speaker: Henry W. Fisher.

DIRECTORS MEETING, NEW YORK, FEBRUARY 15, 1917

The regular monthly meeting of the Board of Directors was held at Institute headquarters in New York on Thursday, February 15, 1917, at 4:00 p.m.

There were present: President H. W. Buck, New York; Past President P. M. Lincoln, Pittsburgh, Pa., Vice-Presidents C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., William McClellan, New York, B. A. Behrend, Boston, Mass., P. Junkersfeld, Chicago, Ill., L. T. Robinson, Schenectady, N. Y.; Managers Frederick Bedell, Ithaca, N. Y., Bancroft Gherardi, F. B. Jewett and A. S. McAllister, New York, John H. Finney, Washington, D. C., John B. Taylor, Shenectady, N. Y., Harold Pender, Philadelphia, Pa., C. E. Skinner, Pittsburgh, Pa., John B. Fisken, Spokane, Wash., N. A. Carle, Newark, N. J., Charles Robbins, Pittsburgh, Pa.; Treasurer, George A. Hamilton, Elizabeth, N. J.; and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $9,562.57 was ratified.

The report of the Board of Examiners of its meeting held on February 6, 1917 was read and the actions taken at that meeting were approved.

Upon the recommendation of the Board of Examiners 111 Students were ordered enrolled, 78 applicants were elected to the grade of Associate, 2 applicants were reinstated as Associates, 2 applicants were elected to the grade of Member, and 7 applicants were transferred to the grade of Member.

Upon the request of Professor J. F. Stevens of the University of North Dakota, and with the approval of the Chairman of the Committee on Students Branches, the organization of a Branch at that university was authorized.

The Executive Committee reported having held special meetings on February 6th and 9th for the purpose of preparing and issuing to the membership, a circular and data sheet for classifying members with regard to their availability for military or naval service in case of need. The action of the Executive Committee in preparing and sending out this circular and data sheet was approved.

A considerable amount of other business was transacted by the Board, reference to which will be found in this and future issues of the PROCEEDINGS.

ENGINEERS IN NATIONAL DEFENSE

The response to the Military Classification Data circular sent out under date of February 8, by the Executive Committee to the Institute membership has been very gratifying, and over 1200 data sheets are now in the hands of the special committee of the Institute for classification.

These data sheets are being taken up individually as received, and turned over to the various departments of the Army and Navy for consideration, and in a short time further information will be sent to those members who have mailed their filled-out blanks, which will indicate the channels through which the members can, in the most effective way, deliver their particular services to the Government.

During the Midwinter Convention in New York, addresses were made by Major J. H. Finney, of the Engineer Reserve Corps and Captain J. H. Cuntz, of the Signal Officers' Reserve Corps, explaining some of the most important ways in which engineers could be of service to the country in case of war. Major Finney spoke in part as follows.

EXTRACTS FROM MAJOR FINNEY'S ADDRESS

Mr. Buck has suggested that I elaborate somewhat on the circular that was sent out by the Institute and

Digitized by Google

clarify some of the points which may not be quite clear to many of us who do not know a great deal about the military side of the country.

The time is actually here when we as leaders in the science of electrical engineering, and skilled in many of the essential things on which modern warfare is based must make good our claim for constructive leadership and assume as a bounden duty the responsibility that the present critical situation lays upon us.

How can we as engineers and citizens best serve? There are many ways already provided—many branches of service both combatant and special, and I shall as briefly as possible recite some present conditions and show what kinds of service are open to us.

Our army, as good as any of the world, man for man, but only in that respect, because of the woeful deficiency of modern equipment of machine guns and field artillery, has an authorized strength in line and staff of 133,166 men. In December the actual strength was 109,959—23,207 vacancies. The National Guard even if it were effective in men, officers and equipment, which it is not, if it were possible to effectively combine it with our regular army, would make less than 250,000 men where a million or two million or more might be required to operate against a first class power.

It is fair to assume that some day we shall have in America universal military training and service, through which we may create more or less of a real defensive army, but the nearest thing to it now existing is the voluntary military training and service provided by the act of last June creating the reserve corps through which it is hoped to secure a reserve of officers having more or less military training, for service as temporary officers in the army in time of war and in the case of the engineer corps and signal corps, of securing enlisted men for these two branches as well. This reserve has an obligatory service of 15 days per annum for instruction in camp with pay of the rank, and is subject to active duty on the call of the president in case of war or threatened hostilities, of course with pay. In the engineers officers reserve corps this duty is of two kinds, Class A being duty with the combatant troops, Class B being special duties of a civilian nature as were shown by the Institute's circular. I need not go into detail as to qualifications required for these commissions other than to say that most of our members if physically fit can qualify in one branch or another and render efficient service.

I believe that we shall be able to obtain from the national engineering societies all of the engineering and technical officers that we shall require, but it is of course perfectly obvious that from the military side they will not be particularly effective without a great deal of training; but they will improve in that side of the work. I mean effective from the military duty or fighting view-point, but they will be particularly effective in the building of defensive works and increased transportation facilities and coordinating the manifold duties of the engineer corps with industry and fortunately perhaps it is these things rather than fighting that would first engage the attention of the engineer reserve. The War Department has at present about 1200 applications for commissions in the engineer reserve; they are coming at a fairly uniform rate, sometimes as many as thirty a day, so that the officer reserve is working out well. The question of obtaining the enlisted men permitted by the act of June 1916 for the engineer corps, when we consider that we shall need some 50,000 of them for an army of a million men, is a task that will put us on our mettle to perform, but it is a task which we must certainly undertake. This is a real job, because it must be done in the face of an increased demand in industry for just such men, and it presents a many sided problem that cannot be too soon undertaken by the engineers and helped on by each indi-

Digitized by Google

vidual in the national engineering societies.

The opportunity for service does not end there, for the Navy needs men by the many thousands. The estimated present shortage is, officers 1099, men 25,877 and to those whose inclinations lead to saltwater service, the Navy has an attractive reserve force divided into five classes.

There is a great opportunity existing in the Navy for many of the members of the Institute who are answering this circular, and who are capable of taking advantage of it, and many of them are expressing their preference for work in the Navy. I am not here in an official capacity, except as a member of the Institute, and I am not a preacher, because, after all is said, this is a matter that must be put up to one's own conscience to decide; but I cannot close without again emphasizing what I believe to be the real responsibilities of the engineer, and emphasizing the necessity of prompt and united action that will weld our great engineering societies into a compact, efficient, willing and patriotic body, ready for the Country's call.

Extracts from Captain J. H. Cuntz' Remarks

The Signal Corps is the nerve system of the Army. It is the intelligence bureau. It is at the very heart of things and keeps in close touch with everything that is going on.

The duties of the Signal Corps include the transmission of military information involving the use of visual signaling apparatus; the construction, operation, and maintenance of military cables, telegraph and telephone systems, and radio stations; the organization and training of Signal troops; the design and supply of equipment necessary to transmit information required for military purposes, and aeronautics.

To meet these duties, the Signal Corps requires officers with a knowledge of telegraph apparatus, telephones, motor generators, batteries, gas engines, cables, radio apparatus, and similar technical equipment. In addition, aeronautical officers are required as aviators, balloonists, and others who are expert in the technical equipment necessary for the aviation section of the Signal Corps.

From this brief recital you can see why it is preeminently the Corps for electrical engineers.

The Signal Officers' Reserve Corps is a distinct section of the Officers' Reserve Corps and should not be confused with the Engineer Corps, which is another distinct branch.

Commissions as Lieutenants, Captains and Majors will be given to properly qualified men. There are no age limits for these grades. All candidates must pass a physical examination.

The professional examination, in the present emergency, will consist largely in satisfactory evidence of a man's training and experience.

Officers of the Reserve Corps are liable to fifteen days service a year in time of peace, and are subject to call in case of war or threatened hostilities. When called into service they receive the pay of the corresponding grade in the regular Army.

The new head of the Signal Corps is a man well known to electrical engineers the world over, Brigadier-General George O. Squier, who naturally has a fraternal feeling for his colleagues in our profession.

Among the men who have already joined, or are about to join the Signal Officers' Reserve Corps, are our own president Major Buck, and our past-presidents Major Carty and Major Kennelly. A number of prominent officials of the American Telephone and Telegraph Co., The Western Electric Co., the Western Union and the Postal Telegraph Companies are also coming into the Corps, and other members of our Institute who are properly qualified cannot do better than follow the good example which has thus been set for them.

Digitized by Google

A. I. E. E. MIDWINTER CONVENTION

The fifth annual midwinter convention of the A. I. E. E. was held at Institute headquarters, New York, on the 14th, 15th and 16th of February, 1917. All sessions were well attended, the total registration reached 712.

President H. W. Buck, formally opening the convention at 10:45 a.m. Wednesday the 14th, pointed out that the event of the past year of most interest to engineers, and one of the most significant steps in modern progress, was the great strengthening of the spirit of cooperation. In this advancement, he cited, first: The organization of an Engineering Branch by The American Association for the Advancement of Science; second, the arrangement by which A. S. C. E. will make their headquarters in the Engineering Building and become one of the founder engineering societies and also the proposed establishment of an organization probably to be known as the Engineering Council of the United Engineering Societies; third, the appeal for cooperation between engineers and our government, so that they may work together in the most effective manner in case the emergency before the country at the present, develops into war.

President Buck introduced Dr. C. R. Mann of the Carnegie Foundation for the Promotion of Teaching who outlined the report of the committee on engineering education which will shortly be published.

The first of the technical sessions, the Standards Session, was then opened by President Buck calling for the paper by Ralph Kelly, *Internal Temperatures of A-C. Generators.* In the absence of the author, this paper was ably abstracted by Prof. Alexander Gray. The paper dealt with the wide divergence between internal and surface temperatures, with explanation of why average figures cannot be established. The following men took part in the discussion: H. G. Reist, C. A. Adams, W. F. Dawson, H. M. Hobart and A. M. Gray.

Prof. Comfort A. Adams, chairman, called the afternoon session to order at 2:45 p.m. This session was known as the Protective Devices Session and all three papers on the program were read before discussion was permitted. The first paper presented was by J. Allen Johnson, *Reactors in Hydroelectric Stations.* The author described the advantages and limitations of current-limiting reactors. Reduction of synchronous stability was fully explained. Actual occurrence of a surge described. The next paper entitled, *The Effect of Current-Limiting Reactors in Steam Turbine Stations under Short-Circuit Conditions,* by Paul B. Juhnke gave the method of using protective reactors in the Commonwealth Edison Station, Chicago, and the results of experience under short-circuit conditions. The third paper of this session, *Protection of Transformer Neutrals against Destructive Transient Disturbances,* by Max H. Collbohm was presented by John B. Taylor, in the absence of the author. This paper explained the danger at the neutral point of a bank of Y-connected transformers from excessive potentials caused by building up of simultaneous incoming waves. Chairman Adams then called for discussion in which the following men took part: F. H. Kierstead, H. R. Woodrow, A. R. Cheyney, L. F. Blume, W. R. Bullard, J. B. Taylor, R. F. Schuchardt and H. R. Summerhayes. Closures to the three papers were made respectively by J. A. Johnson, P. B. Juhnke and J. B. Taylor.

The Electrophysics Session was called to order at 10:30 a.m. on Thursday with F. W. Peek, Jr. presiding. The first paper of this session *Corona and Rectification in Hydrogen,* by J. W. Davis and C. S. Breese, presented in the absence of the authors by Charles Fortescue, gave the results of an investigation of the formation of corona in hydrogen between a wire and a concentric cylinder. Immediately succeeding this, the paper entitled, *The*

Digitized by Google

Electric Strength of Air-VII, by J. B. Whitehead and W. S. Brown, abstracted by Dr. Whitehead gave the results of a determination of corona-forming voltages for alternating and for positive and negative continuous voltages under similar conditions, and also qualitative indications of the correctness of Townsend's theory of ionization. These papers were discussed by S. Dushman, J. B. Taylor, L. W. Chubb and F. W. Peek, Jr. with a closure by J. B. Whitehead. The third paper of the session *Oscillating Current Circuits by the Method of Generalized Angular Velocities*, by V. Bush, was then read by the author. This paper gave a simple method of obtaining generalized angular velocities, frequencies and decrements of free oscillation by generalizing Kirchoff's law. A discussion followed by A. E. Kennelly, C. Fortescue, H. Fletcher and F. C. Fry with a closure by V. Bush.

The fourth technical session, the D-C. Motor Control session, was called to order by Chairman J. Franklin Stevens at 10:30 a.m. Friday the 16th. Mr. H. D. James presented his paper entitled *Industrial Controllers with Particular References to the Control of D-C. Motors.* From a very complete series of experiments on 15-h.p. and 20-h.p. motors the author determined the practicability with automatic acceleration of one-step short circuit of the armature resistor, and the use of one-step resistance for dynamic braking. The paper by K. L. Hansen, *Analysis of Starting Characteristics of Motors*, read by H. D. James in the absence of the author, gave a derivation of the mathematical expressions for current, speed, torque and power during acceleration of shunt, series and compound motors. These papers were discussed by C. T. Evans, R. G. Widdows, J. H. Albrecht, R. H. McLain, J. B. Fisken, A. M. Gray, R. L. Goetzenberger, R. E. Hellmund, E. J. Murphy, E. H. Martindale, A. A. Gazda, F. W. Gay and C. G. Malott with closure by H. D. James. The final technical session, devoted to A-C. Motor Control was presided over by E. H. Martindale. The first paper, *Transient Conditions in Asynchronous Induction Machines and their Relation to Control*, by R. E. Hellmund, read by the author, discussed a number of transient conditions immediately after changes in circuit connections are made, and the advisability of considering these conditions in control lay-out. *The Performance of Polyphase Induction Motors under Unbalanced Secondary Conditions* was read by the author, A. A. Gazda. This paper gave a demonstration of the practicability under certain conditions of operating polyphase induction motors with unbalanced and single-phase secondaries, making greatly simplified control apparatus possible. A discussion followed by W. B. Kouwenhoven, R. B. Williamson, A. E. Averrett, R. E. Hellmund, A. Simon, A. A. Gazda, H. D. James and C. F. Scott. Closures to both discussions were furnished by the respective authors.

During the convention the following committee meetings were held: Wednesday-Educational, Meetings and Papers, Sub-Committee 28 (Standards); Thursday-Electrophysics, Standards, Membership, Power Stations, Military Classification, Lighting and Illumination, Sub-Committee's Nos. 3, 6 and 20A (Standards) and Board of Directors; Friday-Entertainment Committee.

On Wednesday evening at 7:30 p.m. President Buck gave a dinner to the Board of Directors at the University Club. Following the dinner there was an informal discussion of various matters relating to the affairs and the future development of the Institute.

On Thursday evening at 8 p.m. before a large audience in the auditorium of the Engineering Building R. A. Millikan, President of the American Physical Society and Professor of Physics of University of Chicago, delivered a very interesting lecture in which he called attention to the close relation existing between the growth of engineering in general and advancement in the science of physics. He then cited ten of the

Digitized by Google

most important modern discoveries of physics. Prof. Millikan's lecture will be published in full in a future issue of the PROCEEDINGS. Preceding Prof. Millikan's lecture, Major J. H. Finney, Engineer Reserve Corps and Capt. J. H. Cuntz, Signal Officers' Reserve Corps, delivered addresses which are reviewed elsewhere in this issue.

At the close of Prof. Millikan's lecture a large number of the members and their guests adjoined to Institute headquarters on the tenth floor. An enjoyable social hour was spent and light refreshments were served.

The convention closed on Friday evening with a Dinner-Dance at the Hotel Astor at 7 p.m. This was attended by 329 members and guests.

PAST SECTION MEETINGS.

Baltimore.—January 19, 1917, Public Service Building. Subject: The Public Service Building. The various features of the building were explained by Messrs. Robert E. Lee Taylor, E. H. Tillman, W. R. Moulton, and C. L. Reeder. Attendance 33.

Chicago.—January 22, 1917. Paper: "The Nature of the Power Requirements of the Electrochemical Industry" by F. A. Lidbury. Attendance 80.

Cleveland.—January 15, 1917, Electrical League Rooms, Hotel Statler. Illustrated address by Mr. Norman Anderson on "The Construction and Operation of America's Great Talking Service—The Bell System". Attendance 60.

Denver.—January 19, 1917, Denver Athletic Club. Paper: "Preparedness in Snow Fighting" by W. L. Whitlock. Chairman L. H. Shute and Mr. James G. Doherty discussed Professor Harris J. Ryan's paper on "Porcelain Suspension Insulators" as presented before San Francisco Section on November 24th. Attendance 30.

January 25, 1917, Denver Athletic Club. Visit of Inspection to the United States Mint. Attendance 40.

February 7, 1917, Denver Athletic Club. Dinner of the Section at which Mr. John B. Fisken was the principal speaker. Mr. Fisken spoke on "Section Organization" and "The Washington Water Power Company and Its Development". Attendance 19.

Detroit-Ann Arbor.—January 19, 1917. Paper: "High-Frequency Oscillations and Insulation" by E. E. F. Creighton. Prof. Creighton illustrated his paper by experiments with high-frequency apparatus. Attendance 250.

Fort Wayne.—January 11, 1917. Commercial Club. Address by Mr. Peter Junkersfeld on "Central Station Activities and Their Relation to the Public". Attendance 160.

February 8, 1917, Commercial Club. Illustrated lecture by Mr. T. A. Boyle on "The Sleeve Valve Motor". Attendance 155.

Indianapolis-Lafayette.—January 19, 1917, Lafayette. Joint meeting of the Section in connection with the Annual Convention of the Indiana Engineering Society. Papers: (1) "Cases Before the Public Service Commission During the Past Year" by H. O. Garman; (2) "Public Utility Service as Affected by Local Conditions" by Peter Junkersfeld; (3) "Spark Method of Selecting Steel for Industrial Purposes" by J. F. Keller; (4) "Flow Values Through a Manufacturing Plant" by Harrington Emerson; (5) "Report of Committee on Power Plants"; (6) "Report of Committee on Buildings and Materials of Construction"; (7) "Evolution of Public Utility Regulation" by C. Francis Harding.

Ithaca.—January 19, 1917. Subject: The Three-Phase System in Theory and in Practise". Papers: (1) "Comparison of Delta and Y" by H. C. Emich; (2) "V-Connection" by D. K. Banks; (3) "T-Connection" by H. M. Strong; (4) Effect of Grounds and Unusual Conditions for Delta and Y-Connections" by M. B. Huntington and A. C. Woodward; (5) "Six-Phase Relations" by J. J. Ruiz; (6) "Effect of Higher Harmonics" by Ralph Bown. Papers were illus-

Digitized by Google

trated with experimental demonstrations. Attendance 45.

Kansas City.—January 31, 1917, Y. M. C. A. Paper: "Sign Lighting" by R. D. Obermeyer, presented by Mr. Thompson. Paper was illustrated by lantern slides. Attendance 12.

Milwaukee.—February 14, 1917, Republican House. Illustrated lecture by Prof. Edw. Bennett on Wireless Telegraphy". Attendance 130.

Panama.—January 28, 1917, Balboa. Inspection of Balboa Dry Dock No. 1, conducted by Messrs. A. L. Bell and A. C. Garlington. Attendance 57.

Philadelphia.—January 8, 1917, Engineers Club. Paper: "Industrial Engineering" by C. J. Russell. Attendance 120.

Pittsburgh.—February 13, 1917, Western Pennsylvania Engineering Society. Paper: "Street Lighting Specifications" by W. Edgar Reed. Joint meeting with Illuminating Engineers Society. Attendance 65.

Pittsfield.—January 4, 1917, Wendell Hotel. Illustrated lecture by Mr. E. Blough on "Aluminum and Its Alloys". Attendance 150.

January 18, 1917, Wendell Hotel. Paper: "Ship Propulsion" by W. L. R. Emmet. Paper was illustrated by stereopticon pictures. Attendance 135.

Portland Section.—January 9, 1917. Address by Miss Edna Groves on "Home Economics Electrical". There was an informal dance after the address. Joint meeting with local section of N. E. L. A. Attendance 200.

San Francisco.—January 26, 1917, Engineers Club. Paper: "Some Personal Observations of the Electrification of the Norfolk and Western Railroad" by A. H. Babcock. Attendance 66.

Schenectady.—January 4, 1917, Edison Club. Addresses as follows (1) "New Applications of X-Rays" by Dr. W. P. Davey; (2) "X-ray, A Key to the Structure of Matter" by Dr. A. W. Hull. Lectures were illustrated by stereopticon and motion pictures. Attendance 350.

February 16, 1917, Edison Club Hall. Illustrated lecture by Mr. C. M. Olmsted on "Aircraft Accomplishments and Possibilities". Attendance 375.

February 19, 1917, Union College. Lecture by Prof. W. L. Cathcart on "The Development of Our Fleet and Naval Stations". A number of local organizations were the guests of the Section at this meeting. Attendance 950.

Spokane.—January 19, 1917, Chamber of Commerce. Papers: (1) "Water System of City of Spokane" by A. Lindsay; (2) "Bridge Engineering in City of Spokane" by Morton Mac Cartney. Both papers were illustrated with lantern slides. Attendance 46.

Toledo.—February 7, 1917, Toledo Commerce Club. Paper: "The Development of the Electric Range" by R. D. Wooley. Attendance 16.

Toronto.—January 19, 1917, Engineers Club. Paper: "Steel Conductors for Transmission Lines" by H. B. Dwight. Attendance 55.

February 2, 1917, Engineers Club. Address by Mr. Paul M. Lincoln on "Maximum Demand Meters". Attendance 60.

PAST BRANCH MEETINGS.

Armour Institute.—February 6, 1917. A radio demonstration and lecture by Messrs. R. H. G. Mathews and H. D. Stevers. Attendance 36.

University of Cincinnati.—February 13, 1917. Paper: "Street Cars" by Thomas Elliot. Attendance 27.

Highland Park College.—January 3, 1917. Paper: "Rupturing Capacities of Circuit Breakers" by Stephen Q. Hayes, abstracted by C. Von Lindman. Abstracts of Institute papers by Messrs. C. E. Cutting and E. Floodeen. Attendance 20.

Iowa State College.—January17,1917. Address by Senator P. C. Holdoegel on "The Method of Procedure for Organizing and Financing a Public Utility Company". Attendance 46.

January 24, 1917. Lecture by Mr. C.

Digitized by Google

R. Underhill on "Electromagnets". Attendance 86.

University of Kentucky.—January 15, 1917, Mechanical Hall. Papers: (1) "The Owen Magnetic Car" by M. J. Crutcher; (2) "Installation of Farm Lighting Plants" by L. C. McClanahan; 3) "New Bonding Methods Developed for 150 lb. Rail" by E. K. Robertson; 4) "The Advantages of Using Oil in Transformers" by M. M. Montgomery. Attendance 23.

Lafayette College.—January 20, 1917. Papers: (1) "The Owen Magnetic Automobile"; (2) "Commercial vs. Municipal Stations". Attendance 18.

Lehigh University.—January 18, 1917 Physics Lecture Room. Papers: (1) "The New York Trip of the Senior Electricals" by G. C. Kehrer; (2) "Automatic Motor Control" by W. C. Jackson.

University of Maine.—December 6, 1916. Ilustrated lectures as follows; (1) "Uses and Applications of the G-E. Electric Motor" by E. R. Brawn; (2) "Substations" by W. E. Barrows. Attendance 48.

University of Minnesota.—January 19, 1917. Engineering Auditorium. Illustrated lecture by Mr. C. R. Underhill on "A-C. and D-C. Electromagnets". Attendance 55.

February 13, 1917, Engineering Auditorium. Demonstration and lecture by Mr. Schwartz on "The Automatic Telephone System, and Principles of Operation". Attendance 50.

University of Missouri.—January 15, 1917, Engineering Building. Paper: "Recent Developments in Heating and Cooking Apparatus" by C. J. Hubbard. Attendance 20.

February 5, 1917, Engineering Building. Paper: "Some Important Points in High-Voltage Transformer Design" by D. P. Savant. Attendance 27.

Montana State College.—January 12, 1917, Physics Lecture Room. Illustrated lecture by Mr. A. D. Stewart on "The Manufacturing Activities of the Westinghouse Company and the Opportunities for Students There". Attendance 44.

Nebraska.—February 7, 1917, Electrical Engineering Building. Paper: "Engineering Law" by Prof. Robins. Attendance 30.

Ohio Northern University.—January 24, 1917, Dukes Memorial. Illustrated lecture by Prof. J. A. Needy on "The Steam Turbine". Address by Messrs. C. J. Rew and R. M. Boyle on "Recent Advances in Steam Turbine Design" and "Turbo-Generators". Attendance 38.

February 7, 1917, Dukes Memorial. Papers: (1) "Pelton Water Wheels"; (2) "Water Power Development"; (3) "Big Creek Development". Attendance 24.

Ohio State University.—January 19, 1917, Robinson Laboratory. Paper: "Temperature Effects in Transmission Line Spans" by Mr. Puchstein. Attendance 22.

February 9, 1917, Robinson Laboratory. Lecture by Mr. Johnson on "Electrification of the Chicago, Milwaukee and St. Paul". Short talk by Mr. Linebaugh on "Regenerative Braking". Attendance 49.

University of Oklahoma.—January 16, 1917, Engineering Building. Papers: (1) "Keokuk Hydroelectric Plant" by Arthur Erickson; (2) "Commonwealth Edison Company Plants" by Gilbert Heller; (3) "Inspection Trips" by L. W. W. Morrow. Attendance 22.

February 13, 1917, EngineeringBuilding. Papers: (1) "Application of Electricity in our New Chemistry Building" C. T. Hughes; (2) "Proposed Improvements in the Electrical Engineering Laboratory" by B. S. Schultz; (3) "Two Electric Inventions—The Wireless Picture Machine and the Electric Titan" by J. D. Biggers. Attendance 24.

Oregon Agricultural College.—January 18, 1917. Papers: (1) "The Work of Relining a Tunnel" by Frank Bell; (2) "Speed Control of Motors" by F. A. Roehrig. Attendance 27.

Pennsylvania State College.—January 19, 1917, Address by Prof. Markle

Digitized by Google

on "Incandescent Lamps". Election of officers as follows—president, J. B. Kelly; vice-president, J. T. Brett; treasurer, J. B. Irwin; secretary, T. J. Haworth, Jr. Attendance 40.

February 7, 1917. Address by Prof. Diemer on "Human Engineering". Attendance 33.

Brooklyn Polytechnic Institute.—January 19, 1917, Prospect Telephone Exchange. Inspection trip to the Prospect Exchange of the New York Telephone Company. Attendance 75.

January 30, 1917, Mailloux Library. Illustrated lecture by Mr. R. A. Paine, Jr. on "Distribution System of the Brooklyn Edison Company". Attendance 32.

Syracuse University.—January 11, 1917. Paper: "Development and Construction of the Storage Battery" by M. J. Puente. Attendance 13.

February 8, 1917. Paper: "Manufacture of Tungsten Lamps" by J. G. Coelho. Attendance 15.

February 15, 1917. Discussion on "Municipal Lighting Plant vs. Public Utility Corporation". Attendance 15.

Agricultural and Mechanical College of Texas.—January 19, 1917. Papers: (1) "Possibilities of Hydroelectric Developments in South America" by J. A. Darby; (2) "The General Electric Plants" by W. G. James. Attendance 36.

University of Texas.—January 26, 1917. Papers: "Interior Illumination and Decotative Exterior Lighting" by L. M. Krausse; Illustrated lecture by Prof. J. M. Bryant on "Street Lighting". Attendance 38.

Virginia Polytechnic Institute.—January 9, 1917, Science Hall. Brief address on work done by V. P. I. men at the General Electric Plant. Address by Prof. S. R. Pritchard on "The National Electric Light Association". Attendance 62.

January 24, 1917. Address on "Some of the New Branches of Work that the General Electric Company has Taken Up" by H. B. Pfifer. Attendance 51.

University of Virginia.—January 23, 1917, Engineering Building. Reports on "The Electric Progress of 1916" were given as follows—"Electric Traction" by J. H. Moore; "Prime Movers" by Chas. Henderson; "Electric Ship Propulsion" by A. S. Wise; "Electric Vehicle" J. M. Malle; "Radio Telegraphy" by T. R. Bunting. Attendance 16.

University of Washington.—January 10, 1917, Forestry Hall. Lecture by Mr. G. H. Moore on "Hydroelectric Fieldwork". Attendance 19.

REINSTATED TO MEMBERSHIP FEBRUARY 15, 1917

DYCHE, HOWARD EDWARD, Assistant Professor of E. E., University of Pittsburgh, Pittsburgh, Pa.

RIPLEY, CHARLES MEIGS, General Electric Company, Schenectady, N. Y.

MEMBERS ELECTED FEBRUARY 15, 1917

CUTTING, FULTON, President, Cutting & Washington Inc., 26 Portland St., Cambridge; res., Beverly, Mass.

MCGOWAN, HENRY E., Assistant Secretary, Brooklyn Union Gas Co. and Subsidiaries, General Manager, Flatbush Gas Co., 176 Remsen St., Brooklyn, N. Y.

MUNROE, HAROLD KNAPP, Assistant Superintendent of Power and Equipment, Tacoma Railway & Power Co.; res., 1726 N. Steele St., Tacoma, Wash.

TRANSFERRED TO THE GRADE OF MEMBER FEBRUARY 15, 1917

BARRETT, SAMPSON KIRBY, Assistant Professor of Electrical Engineering, Polytechnic Institute, Brooklyn, N. Y.

BLISS, LOUIS DENTON, President, Bliss Electrical School, Washington, D. C.

Digitized by Google

DILLON, EDWARD PAUL, Assistant Manager, Railway & Lighting Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

EDGECOMB, HENRY R., Chief Engineer, Speer Carbon Co., St. Marys, Pa.

GORSUCH, WILLIAM SCHROFIELD, Engineer of Economics, Interborough Rapid Transit Co., New York, N. Y.

GREENLAND, SAMUEL WILSON, General Manager, Fort Wayne & Northern Indiana Traction Co., Fort Wayne, Ind.

MULRONY, MARION A., Chief Engineer, Shaw Wireless Ltd., Sydney, Australia.

RECOMMENDED FOR TRANSFER, FEBRUARY 6, 1917

The Board of Examiners, at its regular monthly meeting on February 6, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

HUNT, FRED L., Chief Engineer, Turners Falls Power & Electric Co., Greenfield Electric Light & Power Co., Amherst Gas Co., Easthampton Gas Co., Agawam Electric Co., Ludlow Electric Light Co., Greenfield, Mass.

To Grade of Member

DYCHE, HOWARD EDWARD, Assistant Professor of Electrical Engineering, University of Pittsburgh, Pittsburgh, Pa.

MEYER, FRANK J., Chief Electrical Engineer, Oklahoma Gas & Electric Co., Oklahoma City, Okla.

ASSOCIATES ELECTED FEBRUARY 15, 1917

ANDERSON, GEORGE LINCOLN, Draughtsman, Bell Telephone Co. of Pennsylvania, 1631 Arch St.; res., 3105 Frankford Ave., Philadelphia, Pa.

*ASIRE, HORACE W., Electrical Engineer, Quick Action Ignition Co.; res., 113 E. Tutt St., South Bend, Ind.

BARNS, FREDERICK BALSTON, Operating Engineer, Philadelphia Electric Co.; res., 4132 Girard Ave., Philadelphia, Pa.

BERNHARD, ALBERT H., Senior Student of Electrical Engineering, Polytechnic Institute of Brooklyn; res., 92 Woodruff Ave., Brooklyn, N. Y.

BERTRAND, WILFRED EDISON, Superintendent of Power, Woodbine Land & Improvement Co., Woodbine, N. J.

BRADSHAW, WILLIAM M., Meter Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 400 Whitney Ave., Wilkinsburg, Pa.

*BURBECK, WILLIAM B., Engineering Work, Sales Dept., Pacific Gas and Electric Co., 445 Sutter St., San Francisco; res., 32 Napier St., Oakland, Cal.

BUTCHER, WILLARD F., Yonkers Electric Light & Power Co., Yonkers; res., 601 W. 151st St., New York, N. Y.

CHADWICK, RALPH H., Assistant Engineer, Transformer Dept., General Electric Co.; res., 836 W. Washington Blvd., Fort Wayne, Ind.

DELEHANTY, WALTER JOHN, Construction Foreman, Pacific Coast District, General Electric Co., 814 Rialto Bldg., San Francisco, Cal.

*EGEE, GEORGE BENTON, Telephone Engineer, Bell Telephone Co.; res., 2045 N. 8th St., Philadelphia, Pa.

FALLON, WALTER ADDISON, Engineer and Statistician, Western Colorado Power Co., Montrose, Colo.

*FAULKNER, LESLIE WILLIAM, Druggist, Watson Faulkner; res., 806 S. Third St., Champaign, Ill.

FEDOTOFF, NICOLAS V., Automatic Developing Dept., Western Electric Co., 463 West St.; res., 2299 Loring Place, New York, N. Y.

*FERGUSON, ROBERT SINDORF, Instructor in Mathematics and Electrical Laboratory, Throop College of Technology; res., 1640 N. Fair Oaks Ave., Pasadena, Cal.

*FISHER, CLARENCE WILSON, Distribution Inspector, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia; res., Ambler, Pa.

Digitized by Google

GIBSON, OTIS, Civil Engineer, Keystone Dredging Co.; res., 355 Fair Oaks St., San Francisco, Cal.

GRATIOT, JAMES T., Manager, Machinery Dept., Fairbanks, Morse & Co., 1735 Wazee St.; res., 1533 Madison St., Denver, Colo.

*GROSSBARD, SOL, Junior Electrical Engineer, Public Service Commission, New York; res., 1067 E. 14th St., Brooklyn, N. Y.

*GUEST, HAROLD E., Draftsman, Worcester Electric Light Co.; res., 206 West St., Worcester, Mass.

*HANSEN, HERBERT CECIL, Superintendent, Bristol Gas & Electric Co., Bristol, Va.-Tenn.; res., 412 Sixth St., Bristol, Tenn.

HARTENSTEIN, HUGO, Vice-President, Chas. H. Thrall Electrical Construction Co., Neptuno and Monserrate, Havana, Cuba.

HAYWARD, THOMAS J., Superintendent, Panama Telephone Co., Panama, R. P.

*HIMMELSBACH, JESSE RUSSELL, Student, University of Washington; res., 4629 21st Ave. N. E., Seattle, Wash.

*HORNER, OLIVER HOWARD, Electrical Engineer, Block & Veatch; res., 1918 N. 17th St., Kansas City, Kans.

*HOWARD, DAVID GOODALE, Instructor in Electricity and Electrical Machinery, Carnegie Institute of Technology, Pittsburgh; res., 1429 Montier St., Wilkinsburg, Pa.

HUBER, WILLIAM EDWARD, Secretary and General Manager, Electric Railway Improvement Co.; res., 1309 W. 105th St., Cleveland, O.

*KEHL, ROBERT JOSEPH, Mechanical Engineer, Oxweld Acetylene Co.; res., 7141 Normal Ave., Chicago, Ill.

KETTLEWELL, JOSEPH EARL, Power Plant Foreman, Yukon Gold Company, Iditarod, Alaska.

*KEWIN, GEORGE EDWIN, Construction Electrical Engineer, Hydro-Electric Power Commission of Ontario; res., 565 Church St., Toronto, Ont.

*KISTLER, ROY EMANUEL, Night Foreman, Power Transformer Testing Dept., General Electric Co., Pittsfield, Mass.

*KRAFT, CHRIS H., Assistant Engineer, Electric Co. of Missouri; res., 18 W. Cedar, Webster Groves, Mo.

KREY, BENJAMIN H., Electrical Engineer, New York Central Railroad Co., Grand Central Terminal; res., 521 W. 112th St., New York, N. Y.

LAFEVER, HAROLD H., Assistant Field Engineer, Gibbs & Hill, Pennsylvania Station, New York, N. Y.; res., Welch, W. Va.

LAIS, RAYMOND A., Superintendent, Electric Products Co., 1067 E. 152nd St.; res., 566 E. 117th St., Cleveland, O.

*LATIMER, CHESTER W., Assistant Electrical Engineer, Marconi Station, Louisburg, N. S., Canada.

*LEDERMANN, FRANK, Senior Student in Electrical Engineering, Brooklyn Polytechnic Institute; res., 882 Anthon Ave., Brooklyn, N. Y.

*LIST, EDGAR GEORGE, Maintenance Engineer, Utah Power & Light Co., Olmsted, via Provo, Utah.

*MAHAN, JOHN HENRY, Specification Writer, Bell Telephone Co., 1211 Arch St., Philadelphia, Pa.; res., 314 S. Clinton Ave., Trenton, N. J.

*MCGUIRE, JOHN PERRY, Construction Foreman, Construction Dept., General Electric Co., Schenectady, N. Y.

*MCLAY, ANGUS DANIEL, Sales Engineer, Detroit Edison Co.; res., 37 Alexandrine Ave. E., Detroit, Mich.

*MENDENHALL, CHARLES ALEXANDER, Telegraph and Telephone Engineer, Interstate Commerce Commission, San Francisco; res., 2006 48th Ave., Oakland, Cal.

*MERTZ, KARL J., Assistant to Electrical Engineer, Electric Power Dept., St. Paul Gas Light Co.; res., 523 Laurel Ave., St. Paul, Minn.

METZGER, A. BURTON, Inspector, 123 William St., New York; res., 4804 Eleventh Ave., Brooklyn, N. Y.

Digitized by Google

MOREY, LEONARD, Sales Engineer, Electric Products Co., 1067 E. 152nd St.; res., 1840 E. 81st St., Cleveland, O.

MORROW, LINN OSBORN, Sales Engineer, Cutter Electrical & Mfg. Co., 19th & Hamilton; res., 4502 N. Seventh St., Philadelphia, Pa.

NELSON, JOHN EDWARD, Salesman, Hertner Electric & Mfg. Co.; res., 10113 Hempden, Cleveland, O.

*NOE, EDWARD T., Jr., Meterman, Testing Laboratory, Philadelphia Electric Co.; res., 3311 N. 17th St., Philadelphia, Pa.

NORTON, FAY ARTHUR, Engineer, Cutler-Hammer Mfg. Co.; res., 172 16th St., Milwaukee, Wis.

NOTVEST, GUILLAUME ROBERT, General Foreman, Switchboard Dept., Electric Products Co., 1067 E. 152nd St., Cleveland; res., Mosspoint, Euclid, O.

*PATTEE, CLYDE, Plant Dept., Oregon-Washington Telephone Co., Hood River, Ore.

*PERRY, WILLIAM WALTER, Superintendent of Substations, Pennsylvania Utilities Co.; res., 33 N. 9th St., Easton, Pa.

REED, ALEXIS JOSEPH, Engineer, Equipment Dept., Pacific Telephone & Telegraph Co., 623 Sheldon Bldg., San Francisco; res., 5920 Colby St., Oakland, Cal.

RITTER, JAMES BRADFORD, Cadet Engineer, Philadelphia Electric Co.; res., 180 E. Walnut Lane, Germantown, Philadelphia, Pa.

*ROBERTS, SPENCER, Assistant Engineer, Bureau of Engineering, Public Service Commission of Pennsylvania, 129 N. 4th St., Harrisburg, Pa.

*ROBINSON, GORDON DUDLEY, Instructor, Electrical Engineering Dept., Pennsylvania State College; res., 223 E. Nittany Ave., State College, Pa.

RUDIN, O. W., Office Engineer, Union Traction Company of Indiana; res., 917 Chase St., Anderson, Ind.

SALBERG, JOHN, Representative, Westinghouse Electric & Mfg. Co., 1052 Gas & Electric Bldg., Denver, Colo.

SCHNAKE, HENRY C., General Superintendent, L. K. Comstock & Co., 30 Church St.; res., 552 W. 174th St., New York, N. Y.

SENIOR, DAVID B., Chief Electrician, New York Public Library, 42nd St. & Fifth Ave.; res., 4283 Katonah Ave., New York, N. Y.

*SHAND, ERROL BERTRAM, Power Engineering Div., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 500 Todd St., Wilkinsburg, Pa.

*SHEFFLER, MORRIS, Sales Engineer, Whitlock Coil Pipe Co.; res., 107 Bellevue St., Hartford, Conn.

*SMILEY, GLENN WORTH, Cost, Estimating and Progress Electrical Engineer, Detroit Edison Co.; res., 186 Kirby Ave. W., Detroit, Mich.

STANLEY, FRANK A., Editorial Representative, American Machinist, Hill Publishing Co., New York, N. Y.; res., 21 Mill St., Reno, Nevada.

*STICHT, ROBERT ERNEST, 140 Hillside Ave., Woodhaven, N. Y.

STOKES, CHARLES WILLIAMS, Manager, Siemens Co. of Canada Ltd., 1000 Transportation Bldg.; res., 276 Pine Ave. W., Montreal, Que.

SULLIVAN, FRANK JOSEPH, Plant Supervisor, Michigan State Telephone Co.; res., 296 Cortlandt Ave., Detroit, Mich.

*TAYLOR, ARCHIBALD ROGER, Assistant Superintendent, City Light & Traction Co.; res., 241 S. Quincy St., Sedalia, Mo.

*TEAR, HARRY RAYMOND, Assistant Engineer, Service Div., State Public, Utilities Commission, Springfield; res., 55 S. Anderson St., Aurora, Ill.

TIZLEY, ARTHUR JAMES, General Superintendent, E. F. Caldwell & Co., New York; res., 15 Chester Court, Brooklyn, N. Y.

VAN DER HOEVEN, C., Resident Manager, Lindeteves-Stokvis, 11 Broadway, New York, N. Y.

*WEISS, CHARLES GEORGES A., Maintenance of Electrical Plant, Gimbel Brothers; res., 128 Convent Ave., New York, N. Y.

Digitized by Google

WHEADON, FREDERICK WILLIAM HERBERT, Chief Engineer and General Manager, Adelaide Electric Supply Co. Ltd., Adelaide, South Australia.

WIKLE, HUGH H., Brush Engineer, Nungessor Carbon & Battery Works of National Carbon Co.; res., 17910 Windward Rd., Cleveland, O.

*WILSON, JAMES R., Foreman of Electrical Construction, Pittsburgh Railways Co.; res., 126 Lincoln Ave., Edgewood, Pittsburgh, Pa.

*WILLIAMS, Leonard Harrison, Automatic Attendant, Western Union Telegraph Co.; res., Central Y. M. C. A. Building, Atlanta, Ga.

*WINDER, WILLIAM ALBERT, Testing Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 500 Todd St., Wilkinsburg, Pa.

WOLF, KARL, Electrical Draftsman, Chile Exploration Co., 120 Broadway; res., 3151 Decatur Ave., New York, N. Y.

Total 78.

*Former enrolled Students.

APPLICATIONS FOR ELECTIO

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before March 31, 1917.

Adams, R. B., Missoula, Mont.
Allison, F. (Fellow), Detroit, Mich.
Altland, C. P., San Francisco, Cal.
Anderson, O. V., Toronto, Ont.
Ashley, A., New York, N. Y.
Atmore, A. L., Philadelphia, Pa.
Augustine, P., New York, N. Y.
Babbitt, L. A., Philadelphia, Pa.
Bailey, R., Philadelphia, Pa.
Barnes, E. J., (Member), Christchurch, N. Z.
Barrow, G. M., East Pittsburgh, Pa.
Beman, R. H., Atlanta, Ga.
Bennington, E. T., Cleveland, O.
Benneche, H. W., Great Falls, Mont.
Berg, E. E., Spokane, Wash.
Bergman, D. J. R., Santa Clara, Cal.
Billheimer, C. R., Pittsburgh, Pa.
Blakesley, G. R., Baraboo, Wis.
Blum, A.N.(Member), Philadelphia,Pa.
Bond, F. M., Philadelphia Pa.
Bonine, J. H., Philadelphia, Pa.
Braun, W., New York, N. Y.
Broun, L. E., Joliet, Ill.
Brown, J. T., San Francisco, Cal.
Bryans, H.B.(Member),Norristown,Pa.
Byrne, W. S., Omaha, Neb.
Caldwell, P. (Member), Pittsburgh, Pa.
Campbell, W. T., Philadelphia, Pa.
Cardoza, W. H., Ermita-Oriente, Cuba
Garlington, A. C., Balboa, C. Z.
Carter, O. S. Philadelphia, Pa.
Cartmell, R. H., Detroit, Mich.
Cartwright, A. N., Pittsburgh, Pa.
Castleman, D. J., New York, N. Y.
Chappell, W. H., Philadelphia, Pa.
Cheeney, R. C., Medina, O.
Christiansen,K.C.S.,Niagara Falls,N.Y.
Clapp, P. S., New York, N. Y.
Clark, W. J., Pittsfield, Mass.
Cochran, C. E., Cleveland, O.
Conlee, F. M., Madison, Wis.
Cordes, W. B., New York, N. Y.
Cox, H. A., Middletown, N. Y.
Crisfield, J. A. P., (Member), Philadelphia, Pa.
Curry, W. A., New York, N. Y.
Curtis, R. E., Springfield, Mass.
Dane, H. P. L., New York, N. Y.
Davies, J. B., Jr., Birmingham, Ala.
Deming, G. E., Norristown, Pa.
Dewars, A. G., Minneapolis, Minn.
Dieterich, F. C., Norristown, Pa.
Dodd, S. M., Philadelphia, Pa.
Dodge, W. J., San Francisco, Cal.
Dollier,F.E. (Member),Philadelphia,Pa.
Donaldson, R. D. (Member), Philadelphia, Pa.
Drew, E. C., Philadelphia, Pa.
Duff, H. (Member), Allentown, Pa.
Eales, H. W., St. Louis, Mo.
Eilers, R. M., St. Louis, Mo.

Digitized by Google

Elliott, E. B., Syracuse, N. Y.
Ellis, J. W., Hammond, Cal.
Ellis, W. C., Westfield, Mass.
Epstein, S. A., Philadelphia, Pa.
Forsgard, C. H., Childress, Tex.
Fouraker, L. L., Philadelphia, Pa.
Fraser, D. M., (Member), Toronto, Ont.
Frazier, B. R., Pittsfield, Mass.
Frisby, R. L., Chicago, Ill.
Fuller, H. L., St. Louis, Mo.
Galajikiau, H., Chicago, Ill.
Goll, W. S., Ft. Wayne, Ind.
Goodnow, F. E., Chicago, Ill.
Gravell, J.H. (Member), Philadelphia, Pa.
Green, H. H., Brooklyn, N. Y.
Grossman, P., Milwaukee, Wis.
Gugg, A. M., Denver, Colo.
Hagensick, E. H., Omaha, Neb.
Haines, L., Philadelphia, Pa.
Haines, W. H., New York, N. Y.
Hale, W. K., Denver, Colo.
Hall, E. C. (Member), Washington, D.C.
Hall, H. G., Mt. Clemens, Mich.
Hall, L. T., Philadelphia, Pa.
Harbaugh, W. M., Kansas City, Mo.
Hart, R. D., Spokane, Wash.
Hayes, J. M., Philadelphia, Pa.
Hazzard, R. T., Hammond, Cal.
Heinritz, W. J., Philadelphia, Pa.
Hennessey, M. J., Philadelphia, Pa.
Hersh, H., Milwaukee, Wis.
Hillemeyer, J. E., Webster Groves, Mo.
Hornberger, E. J., Philadelphia, Pa.
Hubbell, J. W., Philadelphia, Pa.
Husted, N. C., Brooklyn, N. Y.
Huttinger, W. R. (Member), Philadelphia, Pa.
Ingham, C. R., Cedar Rapids, Ia.
Ivanovski, G.L. (Member) New York N.Y.
Jansen, E. C., Denver, Colo.
Jenkins, J. E., Philadelphia, Pa.
Johnson, C. F., Richmond, Va.
Johnson, L. C., Spokane, Wash.
Jones, P. S., Milwaukee, Wis.
Joyce, J. B., Jr., Montclair, N. J.
Kaumheimer, E. A., Milwaukee, Wis.
Kimmel, W. L. (Member), Spokane, Wash.
Knowles, W., El Paso, Tex.
Koch, H. J., Milwaukee, Wis.
Kressly, H. C., Philadelphia, Pa.
Lamb, F.B. (Member), Charleston, W.Va.
L'Hommedieu, W.P., San Francisco, Cal.
Little, E. W., New York, N. Y.
Louden, J. G., Philadelphia, Pa.
Lucas, H. N., Philadelphia, Pa.
MacGillivray, H., New York, N. Y.
Mancha, R., St. Louis, Mo.
Marklewitz, E. A., Denver, Colo.
Mathews, C. E., Philadelphia, Pa.
Mathews, I. B., Toledo, O.
McCracken, W.W. (Member), Columbus, Ohio.
McDonald, D. P., Ft. Wayne, Ind.
McFarland, H., Cleveland, O.
McIver, M. G., Newport News, Va.
McLeod, W. R., Jersey City, N. J.
Mellett, J. E. (Member), Atlanta, Ga.
Merrill, B. M., Spokane, Wash.
Meyers, W. H., Bridgeton, N. J.
Mitchell, W. A., Denver, Colo.
Moore, N.S., (Member), Philadelphia, Pa.
Moore, R. V., Sylva, N. C.
Neel, W. T., Philadelphia, Pa.
Nesbitt, F. C., Columbus, O.
Nevraumont, L. J., San Francisco, Cal.
Nichols, J. B., Spokane, Wash.
Nosek, L. F., Cleveland, O.
Nugent, F. R., New York, N. Y.
Olsen, B., Spokane, Wash.
Olsen, H. N., Bayonne, N. J.
Ong, C. G., Indianapolis, Ind.
Ott, E. H., Cleveland, O.
Oxer, G. C. (Member), New York, N. Y.
Palme, A., Pittsfield, Mass.
Parmenter, R. J., Chicago, Ill.
Patitz, G. J., Chicago, Ill.
Paustian, F. H., Omaha, Neb.
Peabody, D. W. (Member), Atlanta, Ga.
Penney, F. H. (Member), Schenectady, N. Y.
Perkins, R. P., Philadelphia, Pa.
Perley, F. G., Allentown, Pa.
Pierce, C. A., Buffalo, N. Y.
Pike, P. H., Philadelphia, Pa.
Pillai, N. K., Assam, S. India
Pomeroy, G. A., Ann Arbor, Mich.
Ponsonby, A. A., Wilmington, Del.
Prior, H. E., Washington, D. C.
Prout, C., Springfield, Ill.
Putnam, W. J. (Member), Urbana, Ill.
Quayle, L. A., Cleveland, O.
Quinton, T. C., Chicago, Ill.
Rabbe, O. F., Toledo, O.
Reddie, W. W., East Pittsburgh, Pa.
Rhodes, M. A., Gilmore, City, Ia.

Digitized by Google

Rhodes, S. A., Chicago, Ill.
Ritter, W. H., Chicago Heights, Ill.
Roberts, E. A., Urbana, Ill.
Roberts, W. S., Rock Hill, S. C.
Sargl, G., Boston, Mass.
Saunders, G. A., Toronto, Ont.
Saunders, L., East Pittsburgh, Pa.
Schneider, F. J., Philadelphia, Pa.
Schroeder, G. (Fellow), Manchester, England
Seares, L. V., Denver, Colo.
Sharples, A. R., Philadelphia, Pa.
Shurts, G. J., Perth Amboy, N. J.
Sifton, E. I., Hamilton, Ont.
Sigman, J., Philadelphia, Pa.
Silbert, R. H., Philadelphia, Pa.
Silva, A. D., Cleveland, O.
Sinelnick, H. B., Jr., New York, N. Y.
Sloan, R. D., Bozeman, Mont.
Smith, B., Chicago, Ill.
Smith, I.B., (Member), Philadelphia, Pa.
Somes, H. E., Buffalo, N. Y.
Stewart, L. D., Hurley, Wis.
Stuart, F. C. (Member), Joliet, Ill.
Tann, W. L., Schenectady, N. Y.
Taylor, R., Philadelphia, Pa.
Taylor, W. E., Manchester, England
Thomson, G. C., Brooklyn, N. Y.
Thompson, H. E., Jr., Chicago, Ill.
Tideman, H. L. T., Chicago, Ill.
Tomlinson, J. T., Etna, Pa.
Tompkins, E. M. (Member), Chicago, Ill.
Vickery, W.O. (Member), Trinidad, Colo.
Volentine, P., Jersey City, N. J.
Walker, H. N., Philadelphia, Pa.
Walker, H. N., Spokane, Wash.
Ward, G. A., Milwaukee, Wis.
Warnick, J. H., Philadelphia, Pa.
Watson, F. H., Philadelphia, Pa.
Wetzel, W. C., Sharpsburg, Pa.
Williams, S. B., Philadelphia, Pa.
Williamson, H. M., Chicago, Ill.
Wilson, A. R. (Member), Waco, Tex.
Woodruff, B. H., Atlanta, Ga.
Wright, G. I., Portland, Ore.
Yates, P. B., St. Catherines, Ont.
Zoll, R. C., Los Angeles, Cal.
Total 207

STUDENTS ENROLLED FEBRUARY 15, 1917

8688 Mauk, C. E. Ohio State Univ.
8689 Merton, E. J., Ohio State Univ.
8690 Leon, L. K., Ohio State Univ.
8691 Bender, H. D., Ohio State Univ.
8692 Kindl, C. H., Carnegie Inst. Tech.
8693 Levesque, L., Univ. of Toronto
8694 Sumner, W. A., Yale University
8695 Pinney, A. J., Univ. of Wisc.
8696 Nelson, C. E., Throop Coll. Tech.
8697 Kent, E. R., Mass. Inst. Tech.
8698 Cowgill, L. B., Univ. of Wash.
8699 Chamberlain, L. L., Ohio Northern Univ.
8700 Varcoe, L.R., Kans. State Agri. Coll.
8701 Glasser, C. E., Univ. of Nebr.
8702 Windham, A. C., Univ. of Ala.
8703 Stein, R. B., Purdue Univ.
8704 LaBagh, L.J., Poly. Inst. of Bklyn.
8705 Hotchkiss, G., Poly. Inst. of Bklyn.
8706 Baxter, J. H., Univ. of Okla.
8707 Aubert, F., Cornell Univ.
8708 Herskowitz, L., Cornell Univ.
8709 Jones, H. W., Jr., Cornell Univ.
8710 Lopez, F. F., Cornell Univ.
8711 McCune, J. E., Cornell Univ.
8712 Jennings, A. G., Cornell Univ.
8713 Myers, J. L., Cornell Univ.
8714 Noll, L. H., Bucknell Univ.
8715 Jackson, W.L., A. & M. Coll. of Tex.
8716 Brickson, R. A., Colo. Agri. Coll.
8717 Feist, S., Stevens Inst. Tech.
8718 Corliss, L. F., Cornell Univ.
8719 Jevend, E. C., Univ. of Minn.
8720 Wiatt, F. E., Bliss Elec. Sch.
8721 Gladden, L. C., Ohio State Univ.
8722 Ballinger, J. G., Univ. of Toronto
8723 Smith, C. F., Univ. of Penna.
8724 Gettlin, A. A., Univ. of Penna.
8725 Billstein, A. E. F., Univ. of Pa.
8726 Zippler, W. N., Univ. of Penna.
8727 Leopold, C. S., Univ. of Penna.
8728 Avery, L. J., Wentworth Inst.
8729 Wilmeth, R. H., Univ. of Texas
8730 Burkhart, C. S., Univ. of Texas
8731 Wear, J. P., Jr., Univ. of Texas
8732 Zuhlke, E., Jr., Univ. of Texas
8733 Finlay, O. E., Univ. of Texas
8734 Travers, N. E., Univ. of Texas
8735 Clark, C. W., Univ. of Texas
8736 Penn, D. M., Univ. of Texas

Digitized by Google

8737 Morrison, G. K., Univ. of Cal.
8738 Arbuckle,R.M.,Washington Univ.
8739 Garrett, C. L., Lehigh Univ.
8740 Whitman, M. A., Univ. of Wash.
8741 Fox, H. N., Mich. Agri. Coll.
8742 Packard, K. S., Wentworth Inst.
8743 Quick, R. S., Univ. of Ill.
8744 Lurie, S. J., Univ. of Ill.
8745 Kliest, W. A., Univ. of Wash.
8746 Rice, G. R., Univ. of Wash.
8747 Ford, A. E., Mich. Agri. Coll.
8748 Dea, R., Wentworth Inst.
8749 Kongsted, L. P., Univ. of Wash.
8750 Lincoln, H. W., Univ. of Mich.
8751 Henry, O., Mich. Agri. Coll.
8752 Sunday, J. L., Penna. State Coll.
8753 Kibler, J. B., Okla. A. & M. Coll.
8754 McElroy, C.E., Okla.A.& M.Coll.
8755 Emmons, C.D., Okla.A.& M. Coll.
8756 Birch, L. W., Ohio State Univ.
8757 Hawker, C. F., Ohio State Univ.
8758 McCall, J. B., Jr., Univ. of Pa.
8759 Spooner, D. C., Jr., Univ. of Pa.
8760 Jones, J. W., Univ. of Pa.
8761 Swisher, A. W., Univ. of Pa.
8762 Whittle, H., Univ. of Pa.
8763 Burstein, M. M., Univ. of Pa.
8764 Godshalk, E. L., Univ. of Pa.
8765 Molitor, F. W., Ohio Nor. Univ.
8766 Engelbart, C.L.,Wash. State Coll.
8767 Friedman,M.C.,ArmourInst.Tech.
8768 Mathews, R. H. G., Armour Inst. Tech.
8769 Fisher, W. H., Penna. State Coll.
8770 Chadwick, G. L., Bliss Elec. Sch.
8771 Cox, C. C., A. & M. Coll. of Tex.
8772 Eagle, J., Ala. Poly. Inst.
8773 Lassiter, W. R., Ala. Poly. Inst.
8774 Andrews, G., Jr., Ala. Poly. Inst.
8775 Henry, E. B., Ala. Poly. Inst.
8776 Chappel, J. A., Ala. Poly. Inst.
8777 Jeffrey, L. L., Ala. Poly. Inst.
8778 Douglas, J. A., Ala. Poly. Inst.
8779 Bryan, C. K., Ala. Poly. Inst.
8780 Barron, W. W., Ala. Poly. Inst.
8781 Bailey, T. W., Ala. Poly. Inst.
8782 Howard, W. J., Ala. Poly. Inst.
8783 Shinholser, W. T., Ala. Poly. Inst.
8784 Pritchett, B., Ala. Poly. Inst.
8785 Weber, G. E., Jr., Ala. Poly. Inst.
8786 Walter, A. B., Jr., Ala. Poly. Inst.
8787 McElhose, I. H., Rensselaer Poly. Inst.
8788 Copley, K. M., Lewis Institute
8789 Pearson, O. A., Lewis Institute
8790 Fox, F. H., Kansas Univ.
8791 Glazier, F. S., Univ. of Utah
8792 Brown,E. L., A.& M. Coll. of Tex.
8793 Elliot, R. D., A. & M.Coll. of Tex.
8794 Hanson, G.B., A.&M.Coll. of Tex.
8795 Joyce, J. B., A.& M. Coll. of Tex.
8796 Priester, L. A., Jr., A.& M. Coll. of Tex.
8797 Yates, C. C., A.& M. Coll. of Tex.
8798 Kalogeras, S. G., David Ranken School of Mech. Trades

Total 111

PERSONAL.

MR. H. C. DEFFENBAUGH, who for several years has been cost engineer for the Rochester (N. Y.) Railway and Light Company has resigned to take the position as engineer and assistant to the secretary, Empire State Gas and Electric Association, 29 West 39th St., New York.

MR. C. M. GARLAND, widely known as an expert in steam and gas power engineering, has assumed charge of the newly established Power Department of the Allen & Garcia Company of Chicago. Mr. Garland, a graduate of Vanderbilt University, served a one year apprentice ship with the Bullock Electric Company; then two years with the Union Electric Light and Power, Company of St. Louis. For five years he was instructor in mechanical engineering in the University of Illinois, then for three years became chief engineer of the Producer Gas Department of R. D. Wood & Co. For the last four years he has specialized in the design and construction of power plants.

CHARLES F. GRAY, consulting electrical engineer, of Winnipeg, Manitoba, has been elected controller for the City of Winnipeg for the ensuing year.

MR. R. TSCHENTSCHER, who for the past thirteen years has been connected with the Illinois Steel Company of

Digitized by Google

Chicago, has severed his connection with that company to become general superintendent of steel plant of the Keystone Steel & Wire Co., Peoria, Ill. This plant will be ready for operation in a short time.

MORTON G. LLOYD, formerly technical editor of *Electrical Review and Western Electrician*, has accepted a temporary appointment as associate engineer in the Bureau of Standards, Washington, D. C.

ACCESSIONS TO LIBRARY

This list includes books which have been presented to the library of the A. I. E. E. and the U. E. S. during the past month, not including periodicals and other exchanges.

Some Properties of Vibrating Telephone Diaphragms. By A. E. Kennelly and H. O. Taylor. (Massachusetts Institute of Technology, Electrical Engineering Dept. Bulletin No. 11, April 1916). (Gift of A. E. Kennelly).

UNITED ENGINEERING SOCIETY

A List of American Doctoral Dissertations printed in 1915. Prepared by Alida M. Stephens, Library of Congress. Washington, 1916. (Gift of W. P. Cutter).

American Iron and Steel Institute. List of Officers, Directors, Members, Aug. 1, 1916. New York, 1916. (Gift of Institute.)

American Scenic and Historic Preservation Society, Annual Report. 21st, 1916. Albany, 1916. (Gift of Society.)

Appalachian Engineering Association. Transactions. Vol. VI, Nos. 37, 39, 41-46, 1910. (Gift of Library of Congress.)

Calcium Carbide and Acetylene. Ed. 3. By G. G. Pond. State College, Pa., 1917. (Gift of Henry B. Koons.)

Carnegie Steel Company. Standard Specifications. Steel for bridges, buildings, locomotives, etc. Ed. 6. Pittsburgh, 1917. (Gift of Carnegie Steel Co.)

Catalogue Studies. Vol. 45. (Gift of Catalogue Equipment & Supply Co.)

Coal Tar Pitch. By J. M. Weiss. (Reprint from Journal of Industrial and Engineering Chemistry, Sept. 1916.) (Gift of Barrett Manufacturing Co.)

Concrete Facts about Concrete Roads. Chicago, 1916. (Gift of Portland Cement Association.)

Concrete Sewers. Chicago, 1916. (Gift of Portland Cement Association.)

Concreting in Cold Weather. Chicago, 1916. (Gift of Portland Cement Association.)

Experimental Researches on the Skin Effect in Steel Rails. By A. E. Kennelly, F. H. Achard and A. S. Dana. (Reprinted from the Journal of the Franklin Institute, August, 1916.) (Gift of Massachusetts Institute of Technology, Electrical Engineering Dept.)

Farmer's Handbook on Concrete Construction. Chicago, 1916. (Gift of Portland Cement Association.)

Forests of Worcester County. The results of a forest survey of the fifty-nine towns in the County and a study of their lumber industry. Boston, 1917. (Gift of Massachusetts State Forester.)

Georgii Agricola. Lae de re Metallica. Liber Primus. n.p. n.d. (Gift of E. P. Mathewson.)

International Railroad Master Blacksmiths' Association. Report of the Proceedings of the 24th Annual Convention, 1916. Lima, 1916. (Gift of Association.)

Johnson's Steam Vessels of the Atlantic Coast· New York, Eads Johnson Publishing Co.· 1916. (Gift of Publisher.)

This publication gives a complete list of the coastwise vessels on the Atlantic Seaboard, giving the name, date built, where built, and particulars with reference to the hull, engines and boilers. It is printed in convenient size for the pocket.

Le Système de la Carte au Bureau. By J. Kaiser. Paris, 1914. (Gift of J. Kaiser.)

Michigan Gas Association. Proceedings of 25th Annual Meeting n. p. 1916. (Gift of Association.)

National Advisory Committee for Aeronautics, Annual Report 1st, 1915. Washington 1916.

——General specifications covering requirements of aeronautic instruments. Washington, 1916. (Report No. 8.)

——Nomenclature for Aeronautics. (Report No. 9) Washington, 1916. (Gift of Committee.)

New York (City) Board of Education. Annual Financial and Statistical Report of the Transactions. 1911-1915. New York, 1915. (Gift of C. W. Rice.)

Norwich University, 1819-1911. Her History, her graduates, her roll of honor. Published by G. M. Dodge, compiled and edited by W. A. Ellis. Vol. 3. Montpelier, Vt., 1911. (Gift of W. A. Ellis.)

Old Time Telegraphers and Historical Association. Annual Reunion 35th, 1916. New York, 1916. (Gift of Association.)

Pulverized Fuel for stationary boilers on the Missouri, Kansas and Texas. (Reprint from Railway Mechanical Engineer, Oct. 1916.)

Pulverized Coal (Bulletin No. 10, Oct. 1916. Fuller Engineering Co.)

Pulverized Coal for Open Hearths. (Reprint from Iron Trade Review, Nov. 2, 1916.)

Digitized by Google

GIFT OF LEHIGH CAR, WHEEL AND AXLE WORKS

Sanitary and Engineering Industrial Standards. Union Hill, N. J., 1916. (Gift of New Jersey Department of Labor.)

Stallforth & Company, Inc. Daily fluctuations for October and November 1916 of Bar Silver (No. 1) Mexican Silver Pesos (No. 2), Mexican Fractional Currency (No. 3), Mexican Half dollars in New York (No. 4). (Gift of Company.)

Stallforth & Company, Inc. Daily cable exchange fluctuations for Nov. 1916 of London, No. 1; Paris, No. 2; Berlin, No. 3, and sight Petrograd, No. 4. (Gift of Company.)

State of New York at the Panama Pacific International Exposition, San Francisco, Cal. Feb. 20-Dec. 4, 1915. Albany, J. B. Lyon Co., 1916. (Gift of Publisher.)

Steel Mine Timbers. Tables and data on the properties and uses of sections. Ed. 7. Pittsburgh, 1917. (Gift of Carnegie Steel Company.)

Tentative Valuation by Interstate Commerce Commission, Jan. 9, 1917. Winston-Salem Southbound Railway Company. (Gift of Clemens Herschel.)

The Evening Post. Japanese Supplement. Dec. 30, 1916. New York, 1916. (Gift of C. H. Armstrong.)

Traité d' Analyse. Vols. I-IV. By H. Laurent. Paris, 1885. (Gift of J. F. Springer.)

Traité des Monoyes. Vols. 1-2. By J. Boisard. Paris, 1714. (Gift of E. P. Mathewson.)

Valuation of the property of New Orleans, Texas and Mexico Railroad Company. Before the Interstate Commerce Commission. Dec. 30, 1916. (Gift of Clemens Herschel.)

Valuation of the property of The Kansas City Southern Railway Company and of the properties of its proprietary and subsidiary companies. Before the Interstate Commerce Commission. Filed Dec. 30, 1916. (Gift of Clemens Herschel.)

Waterproofing. Vol. I, Nos. 1, 3 7. New York, 1907-08. (Gift of D. D. Berolzheimer.)

GIFT OF CHARLES A. DOREMUS

Avery, E. M. Elements of Natural Philosophy. N. Y. 1878.

Creation and Deluge. Philadelphia, 1854.

Cavallo, T. Complete treatise of electricity in theory and practice. Lond. 1777.

Daniel, A. Physics for students of medicine. Lond. 1896.

Daniell, J. F. Elements of Meteorology. Vol. I. London, 1845.

Ferguson, Jas. Lectures on select subjects in mechanics, hydrostatics, pneumatics. Lond. 1837.

Gouge, H. A. New system of ventilation. N. Y., 1870.

Kiddle, Henry. Textbook on Physics. N. Y., 1883.

Lardner, Dionysius. Handbooks of natural philosophy and astronomy. First Course. Philadelphia, 1858.

——Popular lectures on Science and Art. 2 vols. N. Y. 1846.

Leger, Theo. Animal magnetism or Psycodunamy. N. Y. 1846.

Loomis, Elias. Introduction to practical astronomy. N. Y., 1855.

Lyon, L. Treatise on lightning conductors. N. Y., 1853.

Matteucci, C. Lectures on the physical phenomena of living beings. London, 1847.

Muller, J. Principles of Physics and meteorology. Philadelphia, 1848.

Noad, H. M. Course of eight lectures on electricity, galvanism, etc. London, 1839.

——Lectures on Electricity. London, 1844.

——Manual of electricity. Vols. I-II London, 1855, 1857.

Peck, W. G. Introductory course of natural philosophy for the use of schools and academies. N. Y. 1866.

Renwick, Jas. Treatise on the steam engine. N. Y., 1830.

Sabine, W. C. Student's Manual of a Laboratory course in Physical Measurements. Boston, 1893.

Sawyer, W. E. Electric Lighting by Incandescence. Ed. 3. N. Y., 1882.

Ventilation of the Capital. Washington, 1871.

Walker, C. V. Complete course of Meteorology. Lond. 1845.

Digitized by Google

EMPLOYMENT BULLETIN

Vacancies.—The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN. The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-206. Wanted: Graduate Electrical Engineer, preferably with one or two years' experience for sales department of a company devoting its energies to the manufacture of alternating-current apparatus. Correspondence confidential. Give all particulars.

V-210. Wanted: Young man with technical education as sales engineer by company manufacturing a-c. motors; one acquainted in or around Cleveland preferred. Give synopsis of education and experience in first letter; also age and height.

V-211. Wanted: An engineer who has a thorough knowledge of the design and application of switches, circuit breakers, and auxiliary apparatus for outdoor substations. Only those having had actual experience will be considered. State in full qualifications and references.

V-212. Sales Manager. Old and established manufacturer of electrical instruments and specialties in the middle West, with twenty district sales branches, desires a technically trained manager for sales department. Energy, ability and qualifications for position more important than experience. Must be experienced correspondent, have sales ability, and know how to get results. State age, training, experience, salary.

V-213. Expert Electrical Draftsman. Good opportunity for one familiar with shop practise and with practical experience in making working drawings for manufacture work. Good knowledge of electrical machinery and fundamental principles of electrical design is necessary, and experience in radio work desirable, but not absolutely essential. Give full particulars regarding age, nationality, experience, etc.

V-214. Wanted: Thoroughly qualified steam efficiency engineer, with operating experience and theoretical training. Duties, which involve travelling, principally examination of large steam turbine plants, analysis of operation and introduction of improvements and economics. Salary adequate for position. Tact a requisite. Replies should give full record of qualifications and experience and should state salary required.

V-215. Wanted: Designing Steam Engineer, familiar with modern turbine and central station practise, office position in New York, with some field work. Operating and construction experience desirable. Reply should give full particulars of training and experience, and salary expected.

MEN AVAILABLE

681. Fellow A. I. E. E., Mem. A. S. M. E., F. I., etc., with broad business and technical training and experience, desires position as executive, manager, or in organization work. Familiar with shop practise, organization, cost systems, etc. Wide experience in operation of power wagons, in their design, construction and purchase. Sales Engineer.

682. Technical Graduate, (1910), six and a half years' experience in central station construction and operating departments, and at present holding responsible position, desires position with engineering or manufacturing concern.

683. Electrical Engineer, technical graduate, 11 years' experience as apprentice, draftsman and engineer, designing and constructing power stations, switchboards, overhead and underground extensions. Wishes position with operating company where hard work and initiative are appreciated.

Digitized by Google

Would consider position at present salary if outlook is good.

684. Young Electrical Engineer, native of Brazil, desires a position with a reliable concern interested in the establishment of an efficient foreign trade with South America. Excellent references.

685. Instructor in Electrical Engineering. Degree of E. E., thorough business training, practical experience, and four years in teaching. Present engagement chiefly laboratory courses. Desires broader opportunity after July 1.

686. Mechanical and Electrical Engineer, graduate Purdue Univ., age 36, four years manager boiler and structural shop, desires similar position with manufacturing or public service company. Several years' experience in power plant work. Tactful, economical, progressive.

687. Metering Engineer. Experienced with instruments of all types and makes; accustomed to both laboratory and operating practise, adjustment, calibration, standardization, oscillograph work and special electrical tests. Will take charge of meter department or electrical testing laboratory with operating concern, or will consider position with manufacturer. Graduate; ten years' practical experience.

688. Assoc. A. I. E. E., with technical education and experience, desires position with a light and power company or railway company. Experience in central station construction, operation and testing. Had G. E. student course, experienced in chemistry, electrical drafting, construction, maintenance of signals, telephone and line transmission. Familiar with electrolysis surveys.

689. Graduate Electrical Engineer (1916); desires position with company manufacturing or dealing in electrical supplies, where opportunity will be afforded to gain a broad experience and a chance for advancement. Any location. Now employed.

690. Professor of Electrical Engineering in a university of high standing, desires to make a change, and will consider position offering opportunities for growth and advancement. My success as a teacher is unquestioned, and I have held responsible positions in engineering and commercial work. Successful writer, and author of two books. Available for summer work in educational, engineering or commercial lines.

691. Electrical Engineer, age 40, married. Twenty years in charge, financial and operating, of lighting, railway and gas properties. Complete charge of hearings—appraisals and rate cases before utility commissions. Desires position of equal responsibility where results count. Will consider a salary and percentage proposition. Slight knowledge of Spanish.

692. Graduate Engineer, 33, married; desires position as superintendent and engineer, or assistant. Ten years' general experience in design, construction, maintenance and operation of the different units of hydroelectric systems. Can handle men and business with tact and ability. Salary to start $1800.

693. Assoc. A. I. E. E., age 25, married, high school and technical education; six years' experience drafting, substation design, power plant work, miscellaneous, motor and experimental test, shop work, and construction foreman in substation construction. Desires position in design or construction; prefer St. Louis locality.

694. Electrical Engineer, technical graduate, with several years' experience in design, construction and operation of railway electrification for heavy traffic, is open for engagement after March 1.

695. Distribution Engineer. Mem. A. I. E. E. Specialist in underground distribution, design and construction, is open for engagement or will design and supervise installations on a commission basis.

696. Engineer-Electrician, age 33, 17 years' practical experience in construction, maintenance and operation of steam, electric and other service supply companies. Location of troubles, clearing same. Specialized electric control and signal systems. Can handle confidential investigations. Technical education nights. Will travel; married; reliable.

697. Graduate Engineer, with ten years' experience in development of electrical apparatus for large manufacturer desires to negotiate for a change in position. Especially familiar with the characteristics of materials used in the construction of such apparatus. Reason for change, the necessity of change of locality. Minimum salary considered, $3,000.

698. Electrical Engineer, capable of handling the electrical design and construction in hydroelectric plants, modern high-tension outdoor and indoor type of substations, small industrial substations, and distributing systems. At present employed, but seeks position of greater responsibilities and opportunities with an optimistic operating or construction company.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917) **SECRETARY.**
GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY.
RALPH W. POPE

LIBRARIAN.
W. P. CUTTER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to March 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.
N. A. Carle, George A. Hamilton,
John H. Finney, William McClellan,
Bancroft Gherardi, J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.
N. A. Carle, Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.
Frederick Bedell, F. W. Peek, Jr.
Philander Betts, F. L. Rhodes,
H. H. Clark, D. W. Roper,
J. G. De Remer, Harris J. Ryan,
H. A. Hornor, T. H. Schoepf
Edward P. Hyde, Charles P. Steinmetz,
L. E. Imlay, N. W. Storer,
E. H. Martindale, Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
Frederick Bedell, L. T. Robinson,
M. G. Lloyd, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 W. 23rd Street, New York.
E. B. Katte, W. I. Slichter,
F. L. Rhodes, Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
J. G. De Remer, A. M. Schoen,
Paul M. Lincoln, J. H. Tracy,
and the chairmen of all Institute Sections, *ex-officio.*

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.
G. M. Baker, W. G. Chace,
S. H. Blake, H. W. Flashman,
E. H. Martindale.
and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
E. A. Carolan, A. M. Hunt,
John J. Carty, William McClellan,
Fredk. Darlington, H. H. Porter,
Gano Dunn, C. S. Ruffner,
John B. Fisken, A. M. Schoen,
L. B. Stillwell,

COMMITTEE ON DEVELOPMENT OF WATER POWER

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.
P. O. Blackwell, Nicholas S. Hill, Jr.,
Francis Blossom, E. A. Lof,
Gano Dunn, W. V. N. Powelson,
L. B. Stillwell.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, H. M. Hobart,
Frederick Bedell, H. D. James,
Joseph Bijur, P. Junkersfeld,
L. F. Blume, A. E. Kennelly,
James Burke, G. L. Knight,
G. A. Burnham, A. S. McAllister,
N. A. Carle, W. M. McConahey,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
W. A. Del Mar, C. E. Skinner,
E. J. Edwards, A. J. Slade,
H. W. Fisher, N. W. Storer,
R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, M. I. Pupin,
B. A. Behrend, E. B. Rosa,
Louis Bell, Charles F. Scott,
James Burke, Clayton H. Sharp,
John J. Carty, Samuel Sheldon,
Gano Dunn, C. E. Skinner,
H. M. Hobart, Charles P. Steinmetz,
John W. Lieb, Elihu Thomson,
R. B. Owens, Philip Torchio.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, Charles A. Terry,
John F. Kelly, B. F. Wood,

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.
A. E. Kennelly, Chairman, Robert T. Lozier,
S. G. McMeen.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.
Charles F. Brush, N. W. Storer,
C. C. Chesney.

Term expires July 31, 1920.
Carl Hering, Harris J. Ryan.

Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.
B. A. Behrend, Paul M. Lincoln,
William McClellan.

Term expires July 31, 1918.
C. A. Adams, Harold Pender,
C. E. Skinner.

Ex-Officio.
H. W. Buck, President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to March 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
100 Broadway, New York.

J. M. Drabelle,
C. C. Egbert,
W. S. Gorsuch,
John Harisberger,
A. H. Kruesi,
Paul M. Lincoln,
Wynn Meredith,
I. E. Moultrop,
S. A. Moss,
R. J. S. Pigott,
Cecil Poole,
E. F. Scattergood,
F. A. Scheffler,
W. R. Thompson,
Philip Torchio,
H. L. Wallau,
B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,
M. T. Crawford,
E. E. F. Creighton,
H. H. Dewey,
P. M. Downing,
H. W. Fisher,
F. A. Gaby,
W. T. Goddard,
O. A. Havill,
R. F. Hayward,
J. P. Jollyman,
P. M. Lincoln,
W. E. Mitchell,
G. J. Newton,
L. C. Nicholson,
W. D. Peaslee,
Stefaan Piek,
C. S. Ruffner,
H. J. Ryan,
F. D. Sampson,
H. E. Shedd,
Julian C. Smith,
P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman.
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,
A. H. Babcock,
Reinier Beeuwkes,
E. J. Blair,
L. P. Crecelius,
J. V. B. Duer,
George Gibbs,
W. J. Harvie,
Hugh Hazelton,
E. B. Katte,
P. J. Kearny,
William McClellan,
John Murphy,
W. B. Potter,
E. D. Priest,
Charles H. Quinn,
Clarence Renshaw,
A. S. Richey,
Charles F. Scott,
John B. Taylor,
H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,
J. H. Davis,
James Dixon,
A. M. Dudley,
Herbert D. Dwight,
F. W. Ells,
J. E. Fries,
F. R. Fishback,
R. H. Goodwillie,
A. L. Hadley,
G. A. Johnstone,
C. A. Kelsey,
C. L. Kennedy,
Charles D. Knight,
A. H. Lawton,
A. M. MacCutcheon,
A. G. Pierce,
James M. Smith,
H. Weichsel,
J. B. Wiard,
R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,
C. E. Clewell,
J. R. Cravath,
T. S. Perkins,
Richard C. Powell,
E. B. Rosa,
W. D'A. Ryan,
Clayton H. Sharp,
W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,
W. H. Blood, Jr.
Fred A. Bryan,
C. L. Cory,
Harry Clifford Eddy,
W. B. Jackson,
A. H. Kruesi,
William McClellan,
Norman C. McPherson,
Allard Smith,
W. G. Vincent,
George W. Wittemore,
Clifton. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
72 W. Adams St., Chicago, Ill .

L. L. Elden,
G. Faccioli,
V. E. Goodwin,
E. M. Hewlett,
Paul M. Lincoln,
A. A. Meyer,
L. C. Nicholson,
N. L. Pollard,
S. D. Sprong,
Philip Torchio,
H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,
F. A. J. Fitzgerald,
A. F. Ganz,
F. A. Lidbury,
F. G. Liljenroth,
Eugene F. Roeber,
J. A. Seede,
R. Tschentscher.

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,
A. C. Crehore,
G. Faccioli,
C. L. Fortescue,
W. S. Franklin,
A. E. Kennelly,
E. B. Rosa,
Harris J. Ryan,
Clayton H. Sharp,
C. P. Steinmetz,
P. H. Thomas,
J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
195 Broadway, New York.

E. F. W. Alexanderson,
R. E. Chetwood,
M. M. Davis,
C. L. Fortescue,
H. M. Friendly,
F. B. Jewett,
S. M. Kintner,
Wm. Maver, Jr.,
Kempster B. Miller,
H. Mouradian,
W. O. Pennell,
Allard Smith,
John S. Stone,
John B. Taylor,
J. L. Wayne, 3rd.
G. M. Yorke,

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.

D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,
M. W. Day,
G. E. Edgar,
W. L. R. Emmet,
W. R. Furlong,
H. L. Hibbard,
Guy Hill,
O. P. Loomis,
G. A. Pierce, Jr.,
H. M. Southgate,
E. A. Sperry,
Wilfred Sykes,
F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,
Frank H. Armstrong,
Graham Bright,
W. A. Chandler,
F. J. Duffy,
L. C. Ilsley,
R. L. Kingsland,
Charles Legrand,
Charles M. Means,
K. A. Pauly,
H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,
F. B. Crosby,
E. Friedlaender,
E. S. Jeffries,
D. M. Petty,
A. G. Pierce,
J. C. Reed,
R. Tschentscher,
Brent Wiley,
R. B. Williamson
J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.

Alexander Gray,
E. J. Henkhe,
E. A. Loew,
William McClellan,
Chester W. Rice,
C. E. Skinner
R. D. Thomson.

Digitized by Google

SPECIAL COMMITTEES.

Revised to March 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
P. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman,
Massachusetts Institute of Technology, Boston, Mass.
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. F. Scott.

PROPOSED RESERVE CORPS OF ENGINEERS.

Bion J. Arnold, Chairman,
105 South La Salle Street, Chicago, Ill.
John Harisberger, A. M. Schoen,
Ralph D. Mershon, Charles W. Stone.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S. McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

Ralph D. Mershon, Paul M. Lincoln,
C. O. Mailloux, John J. Carty.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Harold Pender, Edward D. Adams,
W. I. Slichter, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan,
John J. Carty.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Parley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON JOINT NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly,

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.

Robert Julian Scott, Christchurch, New Zealand,

T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.

W. G. T. Goodman, Adelaide, South Australia.

James S. Fitzmaurice, Perth, West Australia.

L. A. Herdt, McGill Univ., Montreal, Que.

Henry Graftio, Petrograd, Russia.

Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.

A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France.

Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.

John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to March 1, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg.Atlanta,Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St., Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, 433 West Forest Ave., Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Union Tel. Co. Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	Gordon Campbell	M. B. Carroll, G. E. Co., West Lynn, Mass
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7. '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, Pacific Power and Light Co., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	Lucien Buck, 1416 Lake Avenue, Rochester N. Y.
St. Louis.....Jan. 14, '03	A.McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	E. T. J. Brandon	Wills Maclachlan, 910 Excelsior Life Building, Toronto, Ont.
Urbana.....Nov. 25, '02	I. W. Fisk	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	N. J. Rehman	E. C. Hageman, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Marc Holzer	A. C. Maynard, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College. Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col..Jan. 10, '08	R. H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	N. M. Foster	G. M. Bowman, 1517 New Hampshire, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Samuel McC.Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute,Chicago.
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of...May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr., and Mech. Arts. Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of. Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of. Feb 15, '17		
Norwich University....June 28, '16		
Ohio Northern Univ....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University..Dec. 20, '02	H. D. Bender	L. W. Birch, 138 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of....Oct. 11, '12	H. M. Richards	R. E. Heffner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly,	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst..Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of...Dec. 13, '07	C. H. Worthen	C. J. Melrose, State Col. of Wash., Pullman, Wash.
Washington Univ.....Feb. 6, '04	Charles A. Lieber	R. W. MacDonald, Washington University, St. Louis, Mo.
Washington, Univ. of..Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst...Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 58

Digitized by Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI APRIL, 1917 Number 4

A. I. E. E. MEETING IN SCHENECTADY APRIL 13, 1917

The 331st meeting of the American Institute of Electrical Engineers will be held in Schenectady, N. Y., April 13, 1917 under the auspices of the Schenectady Section and the Standards Committee. The official headquarters of the Institute during the meeting will be at the Edison Club, 60 Washington Ave. The technical session will be held at the Mohawk Golf Club, Stop No. 5, Troy Road.

The registration office will be at the Edison Club Hall and will be open at 8:30 a.m. Members and guests are requested to register promptly. At 6 p.m. the registration office will be moved to the Mohawk Golf Club, where guests who arrive late in the afternoon may register.

On Thursday, April 12, 1917, a meeting of the Standards Committee will be held at the Mohawk Club, No. 1 South Church St. at 9:00 a.m. This meeting will probably continue into Friday, and if so the committee will meet at the same place on Friday morning at 9:00 a.m.

The morning and afternoon of Friday will be devoted to various committee meetings, as specified in notices to committee members, and to a Board of Directors luncheon, held at the Mohawk Club, No. 1 South Church St. 1:00 p.m. Several inspection trips have been planned for 2:00 p.m., but on account of the unsettled conditions it is impossible to give very definite information on this subject. An effort will be made, however, to arrange for trips through the Schenectady Works of the General Electric Co., and the American Locomotive Co., Union College and parts of the New York State Barge Canal.

At 6:30 p.m. an informal dinner will be served to members and guests at the Mohawk Golf Club, Dinner tickets should be purchased at the registration office as early as possible.

The technical session will be held at the Mohawk Golf Club at 8:00 p.m. The general subject of the meeting will be *Heating of Electrical Machinery* and a paper will be presented by Mr. V. M. Montsinger entitled *Cooling of Oil-Immersed Transformer Windings After Shut Down*. In addition to the discussion of Mr. Montsinger's paper, discussion will also be called for on four papers as follows: *Internal Temperatures of A-C. Generators*, by Ralph Kelley. This paper was presented at the Midwinter Convention in New York in February 1917 and published in the February PROCEEDINGS. *Electrical Machinery Tests and Specifications Based on Modern Standards*, by H. M. Hobart. This paper was presented at the Toronto Section in September, 1916 and published in the March PROCEEDINGS. *Temperature Distribution in Electrical Machinery*, by B. G. Lamme. This paper was presented at the Chicago Meeting in November, 1916 and published in the November PROCEEDINGS. *Temperature Guarantees for Large A-C. Generators*, by F. D. Newbury. This paper was presented at the Chicago meeting in November, 1916 and published in the November PROCEEDING.

Digitized by Google

All correspondence in regard to hotel reservations should be addressed to the hotel management of any of the following hotels. SCHENECTADY—Mohawk Hotel, Vendome Hotel, Edison Hotel. Those desiring to stop in Albany may obtain accommodations at the Ten Eyck or the Hampton.

A. I. E. E. MAY MEETING

The annual business meeting of the Institute will be held in New York at the Engineering Societies Building, May 18, 1917. At this meeting the report of the Board of Directors is presented and announcement made of the election of officers for the ensuing year. The program for balance of the evening will be announced in the May issue of the PROCEEDINGS.

A. I. E. E. ANNUAL CONVENTION JUNE 26-29, 1917

The Annual Convention of the Institute will be held at Hot Springs, Va., covering the four day period, June 26-29, 1917. The Homestead Hotel has been selected as the headquarters for the convention.

The Meetings and Papers Committee has tentatively decided on five technical sessions. The convention will open on the afternoon of Tuesday, June 26, with President H. W. Buck's address followed by the reports of the various technical committees. The two sessions on Wednesday, the 27th, will be under the auspices of the Transmission and Distribution Committee. The morning will be devoted to the subject of "high-tension cables" and three papers on this subject will be presented, as follows: *Certain Insulation Characteristics of High-Voltage Cables*, by W. S. Clark and G. B. Shanklin; *Problems in Operation and Maintenance of Underground Cables*, by John L. Harper; *Fundamentals of High-Tension Cable Joints*, by D. W. Roper. The afternoon session will be devoted to "high-tension insulators", and four papers will be delivered, as follows: *The Insulator Situation*, by W. D. Peasley; *Porosity of Electrical Porcelain*, by H. J. Ryan; *Expansion Effects as a Cause of Deterioration in Suspension-Type Insulators*, by J. A. Brundige; *Present Practise in the Design and Manufacture of High-Voltage Insulators*, by A. O. Austin. The morning of Thursday, June 28, has been designated as the Mining Session and the following papers will be presented: *Forms of Power Best Suited for the Various Loads Encountered in the Operation of Bituminous Coal Mines*, by R. L. Kingsland; *Test of a Large Mine Hoist*, by R. S. Sage. The fifth and last technical session will be held Friday morning, June 29. The general subject of this session will be inductive interference between railway and telephone lines.

FUTURE SECTION MEETINGS

Baltimore.—April 20, 1917. Subject: Aviation.

Chicago.—April 23, 1917. Subject: Economic Industrial Applications of Electricity.

Detroit-Ann Arbor.—April 13, 1917. Subject: "Thermo-Electric Pyrometry." Speaker: R. B. Lincoln.

Denver.—April 21, 1917. Subject: Electric Hoisting in Mines. Speaker: H. L. Hall.

Fort Wayne.—April 12, 1917, Anthony Hotel. Annual Banquet. Address by Mr. W. B. Potter on "The Electrification of the Chicago, Milwaukee and St. Paul Railway".

Panama.—April 29, 1917. Subject: Tropical Specifications.

Pittsfield.—April 12, 1917. Subject: Patent Law. Speaker: A. G. Davis.

April 26, 1917. Subject: Selecting and Testing of Materials. Speaker: J. A. Capp.

San Francisco.—April 27, 1917. Subject: Rectification.

Spokane.—April 20, 1917. Subjects: High-Tension Transformers. Electrolysis.

Digitized by Google

Toronto.—April 20, 1917. Subject: Railway Economics. Speaker: E. V. Pannell.

A. I. E. E. MEETING IN CHICAGO MARCH 9, 1917

The 330th meeting of the American Institute of Electrical Engineers was held Friday evening, March 9, 1917 in the Hotel Sherman, Chicago, Ill., under the auspices of the Chicago Section and the Protective Devices Committee.

During the morning and afternoon of the 9th the following committee meetings were held: Meetings and Papers Committee, 10:30 a.m.; Industrial and Domestic Power Committee, 12:30 p.m.; Protective Devices Committee, 4:00 p.m. The Board of Directors met at luncheon at the University Club at 1 p.m. as the guests of Past-Presidents L. A. Ferguson and B. J. Arnold and Vice-President P. Junkersfeld. After the luncheon the regular monthly meeting was held, details of which are found elsewhere in this issue.

On Friday afternoon many members took advantage of the opportunities offered of making inspection trips as follows: Electric furnace of Illinois Steel Company; Hawthorne plant of the Western Electric Company. Several very interesting trips were also taken on Saturday morning as follows: Hyde Park office of the Chicago Telephone Company; Snyder electric furnace of the Electric Steel Company; Western Ave. Substation, the Kedzie Ave. car house and the West shops of the Chicago Railways Company; Armours plant at the Stock Yards; thirty members, guests of the General Electric Company, went by special car over the Aurora, Chicago and Elgin and the Elgin and Belvidere to the Automatic Substation at Gilbert.

At 6:30 p.m. an informal dinner was served in the Crystal Room of the Hotel Sherman to about 138 members and guests.

The technical session, held in the Louis XVI room, was called to order by President Harold W. Buck at 8:00 p.m. with about 300 present. Before proceeding with the papers scheduled for the evening Mr. Milton, Chairman of the Chicago Section, made announcements relative to the inspection trips. President Buck then called attention to the new policy of the Institute in holding meetings in various important centers, thus making the Institute a more tangible reality to members outside New York. He then introduced Mr. Philip Torchio who presented his paper entitled "Relays for High-Tension Lines". Mr. R. F. Schuchardt then abstracted his paper entitled "The Protective Relay Equipment of the System of the Commonwealth Edison Company". A discussion followed which was engaged in by the following men; H. R. Summerhayes, W. H. Cole, E. B. Meyer, L. N. Crichton, J. R. Craighead, O. C. Traver, A. A. Meyer, J. B. Taylor, H. L. Wallau, J. S. Jenks, P. Torchio and R. F. Schuchardt.

DIRECTORS' MEETING, CHICAGO, MARCH 9, 1917

The regular monthly meeting of the Board of Directors' was held at the University Club, Chicago, on Friday, March 9, 1917, at 2:30 p.m.

There were present: President H. W. Buck, New York; Past-President Paul M. Lincoln, Pittsburgh, Pa.; Vice-Presidents P. Junkersfeld, Chicago, Ill., L. T. Robinson, Schenectady, N. Y.; Managers John B. Taylor, Schenectady, N. Y.; Charles S. Ruffner, St. Louis, Mo.; and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $12,558.22 was ratified.

The report of the Board of Examiners of its meeting held on March 5 was read and the actions taken at that meeting were approved.

Upon the recommendation of the Board of Examiners, the following action was taken upon pending applications.

Digitized by Google

Upon recommendation of the Board of Examiners 114 students were ordered enrolled, 140 applicants were elected to the grade of Associate, 6 applicants were reinstated as Associates, 1 applicant was reinstated as a Member, 12 applicants were elected to the grade of Member, 4 applicants were transferred to the grade of Member, and 3 applicants were transferred to the grade of Fellow.

Upon the recommendation of the Sections Committee, a petition from 26 Institute members residing in Salt Lake City for authority to organize a Section in that city to be known as the Utah Section of the A. I. E. E., was approved.

A considerable amount of other business was transacted, reference to which will be found in this and future issues of the PROCEEDINGS.

The Board will hold its next meeting at Schenectady, N. Y., on Friday April 13, 1917.

A. I. E. E. NOMINATIONS

At the meeting of the Board of Directors of the Institute held in Chicago on March 9, the report of the Committee of Tellers of its canvass of the nomination ballots cast for candidates for the Institute offices falling vacant July 31, 1917 was presented.

As required by the constitution of the Institute, the Board then selected by ballot its list of "Directors' Nominees," with the following result:

For President: E. W. Rice, Jr., Schenectady, N. Y.

For Vice-Presidents: Frederick Bedell Ithaca, N. Y., John H. Finney, Washington, D. C., A. S. McAllister, New York.

For Managers: Walter A. Hall, West Lynn, Mass., E. H. Martindale, Cleveland, O., Wm. A. Del Mar, New York, Wilfred Sykes, Pittsburgh, Pa.

For Treasurer: George A. Hamilton, Elizabeth, N. J.

The ballots were mailed to the membership the latter part of March, and to be counted must be returned to Institute headquarters, New York, not later than May 1.

REPORT OF COMMITTEE OF TELLERS ON NOMINATION BALLOTS

To the Board of Directors, American Institute of Electrical Engineers.

Gentlemen: This Committee has counted and canvassed, in accordance with Article VI of the Constitution, the nomination ballots received for officers of the Institute for 1917-1918. The result is as follows:

Total number of envelopes said to contain ballots, received from the Secretary		1324
Rejected on account of bearing no identifying name on outer envelope	52	
Rejected on account of having reached Secretary's office after Feb. 28	33	
Rejected on account of ballot carrying signature of voter	0	
Rejected as a duplicate (two ballots received from the same voter, in which case the ballot received last was counted.)	0	
Envelopes received containing no ballots.	37	
Leaving as valid ballots		1202

These valid ballots were counted and the result is shown below:

FOR PRESIDENT

E. W. Rice, Jr	1150
Scattering and blank	52
Total	1202

(The scattering vote was divided among 11 candidates, each of whom received less than 3% of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices.)

FOR VICE-PRESIDENTS

Frederick Bedell	1052
John H. Finney	867
Bancroft Gherardi	737
A. S. McAllister	752
Scattering and blank	198
Total	3606

(The scattering vote was divided among 27 candidates, each of whom received less than 3% of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices.)

Digitized by Google

FOR MANAGERS

William A. Del Mar	1075
Walter A. Hall	1089
E. H. Martindale	1088
Wilfred Sykes	1068
Scattering and blank	488
Total	4808

(The scattering vote was divided among 78 candidates, each of whom received less than 3% of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices.)

FOR TREASURER

George A. Hamilton	1072
Scattering and blank	130
Total	1202

(The scattering vote was divided among six candidates, each of whom received less than 3% of the total vote. Detailed distribution of these votes is shown on the original tally sheets filed in the Institute offices.)

Respectfully submitted,

H. B. P. WRENN, *chairman*
FRANK H. BEALL,
H. B. HAMMOND,
WM. P. WHITE,
W. H. FROST,
Committee of Tellers.

UNITED ENGINEERING SOCIETY
Extracts from President's Annual Report

The important fact of the year 1916 is that on July 25th contracts were executed by which the American Society of Civil Engineers became an additional Founder Society and arranged to make its permanent home in our building. The contracts provide for the construction of three additional stories to the building, the American Society to contribute sum considered equivalent to what each other Founder Society had contributed and to participate in the original Carnegie gift and have an equal share in the property with each other Founder Society.

The construction of the addition to the building is under way, $62,525.04 having been expended thereon in 1916.

This work is in charge of a Building Committee consisting of H. H. Barnes, Jr., Chairman, E. G. Spilsbury, Charles Warren Hunt and Charles F. Rand.

At the request of the Founder Societies, important alterations were made to the lecture halls on the fifth floor of the building to make the same suitable for social functions of the societies.

The Library of the American Society is being merged with the Library of the U. E. S. and the other Founder societies.

At the present time the membership of the four Founder societies is 29,000 and of associate societies 23,000, so that a total of 52,000 engineers now have their headquarters in our building.

The building is at present fully occupied.

The value of the real estate now owned by this Society is $1,647,171.16. This sum will be increased at the end of 1917 by the amount of the cost of the addition to the building.

The income of the Society during 1916 was	$53,062.03
The expenditure was	44,316.20
Gain for the year	8,745.83

Funds for the benefit of the Library were obtained during the year from contributions by the societies of Civil, Mining, Mechanical and Electrical Engineers and the United Engineering Society to the amount of... $15,542.33

From miscellaneous sources	1,750.03
The gross income from searches was	5,382.98
Total	$22,676.34

The securities in the Engineering Foundation Fund were sold and the proceeds re-invested to produce a higher income as shown in detail in the Treasurer's report. The Fund now amounts to $203,374.80

The General Reserve Fund remains unchanged at	$10,000.00
The Depreciation and Renewal Fund is now	71,456.12
The Surplus Account December 31, 1916 is	6,053.25

Digitized by Google

LIBRARY REPORT FOR 1916

The Library Board of the United Engineering Society has published its annual report for 1916, which may be briefly summarized as follows:

The number of readers and visitors to the library during the year was 13,848 or an average of 45 per day. Of these 2,887 made use of the library during the evening after 6 p.m.

The Library Service Bureau issued and distributed a circular entitled "Preparedness for Service". In this pamphlet the various activities of the Bureau are enumerated, the rates for its service tabulated, and a subscription blank for its reference slip service was included. During the year the Bureau fulfilled 1,253 requests for service, classified as follows: search orders, 495; translations, 109; photoprint orders, 637; miscellaneous, 12. Many users of the library require copies of material contained in its files and photoprint copies have been found to be the most satisfactory because diagrams, tables and curves are accurately reproduced. The increased demand for such work made it necessary for the Library to install a photoprinting plant. The total cost of the installation was $1,082.77 and the total number of prints made during 1916 was 4,772.

During the year the collections of the library have been increased by the following accessions: volumes, 2,455; pamphlets, 386; maps, 61; total, 2,902. As a result of the bringing together of the several libraries of the Founder Societies, gifts and purchases, there were a great many duplicates. During 1916 this list amounting to 11,388 volumes of periodicals, textbooks, government publications and pamphlets were sold or given away. The net proceeds, $2,559.70, was added to the Library Endowment Fund. The extent of the library collection on Dec. 31, 1916 was 63,199.

On August 10, 1916 the by-laws affecting the conduction of library work were amended by the U. E. S. Trustees arranging for the admission, August 16, 1916, of the American Society of Civil Engineers as a Founder Society. The A. S. C. E. collection of nearly 90,000 has, therefore, been added automatically to the U. E. S. Library and will be moved shortly to the U. E. S. Building.

As a consequence of the union of the libraries of the Founder Societies a recataloguing must be undertaken in the near future and a study is being made of the cost and most efficient method of classification.

Dr. James Douglas who started our Library Endowment Fund with a gift of $5,000, has added $95,000 thereto. The total of the sum is now $102,559.70. An effort is being made to materially increase this fund as the Library requires the income of a million dollars for its proposed development.

The Library expenses have been as follows:

Library Books purchased	$2,340.88
Library Binding Expense	1,442.55
Library Supplies and Miscellaneous Expenses	1,379.38
Library Salaries	10,923.81
Library Photostat	1,091.02
Library New Lighting Fixtures	132.47
Library Searches Expense	5,366.23
	$22,676.34

The report includes a complete list of donors of books and pamphlets to the library during the year.

Members interested in further details may obtain copies of the report by addressing the Secretary of the Institute

HARRISON W. CRAVER APPOINTED LIBRARY DIRECTOR

Mr. Harrison W. Craver assumes the position of director of the library of the United Engineering Societies of New York on April 1. His new position will put him in charge of what is believed to

Digitized by Google

be the largest engineering library in the world, with approximately 150,000 volumes on technological subjects on its shelves.

In accepting this new charge Mr. Craver resigned the office held since 1908 of chief librarian of the Carnegie Library of Pittsburgh.

With but a year's break, Mr. Craver has been associated with the Carnegie Library of Pittsburgh for 17 years. He was technological librarian from 1900 to 1902, and during that time practically organized that branch of the institution. He returned to that position in 1903, after having spent approximately a year as assistant superintendent of the Allegheny Iron and Steel Company at Brackenridge, Pa., and remained in the technology department until his appointment to the position of chief librarian, nine years ago.

His administration has been one of steady development in the library's history. Under him two of the largest branches of the Pittsburgh library system were built, the Southside branch and the Homewood branch. The circulation of the entire Pittsburgh system has increased from 800,000 in 1908, to 1,500,000 in 1916. The book stock has been increased from 250,000 to 450,000.

Mr. Craver's first contribution to the expansion of the local library system was his organization of the technological library which is now one of the most comprehensive of any in the general public libraries of the country, and which covers, exhaustively, practically every industry in Pittsburgh.

His efficiency in handling the technological branch of the library was due as much to his experience, prior to his entrance in library work, as chemist for steel companies of Leechburg and Pittsburgh, Pa., and Graham, Va., as to his ability as a librarian.

His work in this department, coupled with his special knowledge along technical lines, is said to have brought him the offer from New York, which he has accepted.

JOHN FRITZ MEDAL BOOK

The John Fritz Medal Board of Award which is composed of representatives of four national engineering societies, including the Institute, has published a book giving the history of the Medal, the Rules of the Award, biographical sketches of the medallists, illustrated with portraits, etc. This beautiful book which was designed, engraved and printed by the Bartlett Orr Press, New York, may be obtained by addressing the Secretary of the John Fritz Medal Board of Award, Engineering Societies Building, New York City. Price $2.50 per copy.

PAST SECTION MEETINGS

Baltimore.—February 23, 1917, Johns Hopkins University. Paper: "Electricity in Steel Mills" by K. A. Pauly. Brief report by Dr. J. B. Whitehead on Midwinter Convention of the Institute. Attendance 45.

March 9, 1917, Johns Hopkins University. Paper: "Work of the Bureau of Standards" by S. W. Stratton. Paper illustrated by lantern slides. Attendance 150.

Boston.—February 7, 1917, Auditorium of Boston City Club. Eighth Annual Banquet for engineers of Boston and vicinity, held in conjunction with Boston Society of Civil Engineers, and Boston Section, A. S. M. E. Addresses by Prof. Elihu Thomson, Dr. Hugh Cabot, and Mr. E. H. Ewertz. Toastmaster, Prof. C. A. Adams. Attendance 452.

Chicago.—January 31, 1917, Western Society of Engineers. Paper: "The Relation of Public Utilities to the Public" by W. W. Freeman. Attendance 100.

February 26, 1917, Western Society of Engineers. Paper: "The Making of Rates After Valuation" by William J. Norton. Attendance 80.

Cleveland.—January 15, 1917, Electrical League, Statler Hotel. Illustrated address by Mr. Norman Ander-

Digitized by Google

son on "Construction and Operation of America's Great Talking Service—The Bell System". Attendance 44.

Denver.—February 17, 1917, Denver Athletic Club. Paper: "High-Tension Transmission Line Design and Operation", by L. H. Shute. Attendance 40.

Detroit-Ann Arbor.—January 26, 1917, Detroit Engineering Society Rooms. Paper: "Alternating-Current Generators" by H. H. Higbee. Attendance 22.

February 16, 1917, Engineering Building, University of Michigan. Paper: "Graphical Methods for Handling Engineering Data" by T. R. Running. Attendance 157.

Indianapolis-Lafayette. — February 16, 1917, Indianapolis. Paper: "Electrical Tabulating Machines" by C. A. Tripp. Attendance 25.

Ithaca.—March 2, 1917. Paper: "The Use of the Electric Current in Chemistry" by C. W. Bennett. Attendance 88.

Los Angeles.—February 6, 1917, Blanchard Hall. Illustrated lecture by Mr. W. D'arcy Ryan on "Illumination of the Panama-Pacific Exposition". Joint Meeting with Southern California Chapter of American Institute of Architects and Engineers and Architects Association of Southern California. Attendance 300.

Milwaukee.—March 14, 1917, Republican House. Commander W. A. Moffat in charge of the Great Lakes Naval Training Station gave an illustrated lecture on "Ships of Our Navy". Attendance 150.

Panama.—March 7, 1917, Ancon. Lecture on Military Engineering by Major W. D. A. Anderson. Attendance 245.

Philadelphia.—February 8, 1917, Franklin Institute. Paper: "Modern Dynamo Electric Machinery, with Special Reference to Power and Traction Uses" by Alexander Gray. Attendance 200. Joint Meeting with Franklin Institute.

February 12, 1917. Subject: "The Engineering Graduate and His Opportunities". Speakers: President H. W. Buck on "Institute Work"; Mr. G. P. Baldwin on "Along Commercial Lines"; Mr. W. C. L. Elgin on "The Electrical Public Utility Field". Attendance 250.

Pittsfield.—February 2, 1917, Wendell Hotel. Illustrated lecture by Mr. H. T. Miller on "Iron and Steel from Ore to Finished Product". Attendance 180.

February 15, 1917, F. M. T. A. Hall. Illustrated address by Judge Thomas P. Riley on "The Plattsburg Training Camps". Attendance 150.

March 1, 1917, Hotel Wendell. Paper: "Electrical Porcelain" by E. E. F. Creighton. Attendance 110.

Portland.— February 6, 1917, Multnomah Hotel. Paper: "The Newest Chemical Element—Electricity" by William Conger Morgan. Attendance 72.

Rochester.—January 12, 1917, Engineering Society Rooms. Paper: "Modern Electric Elevators and Elevator Problems" by David Linquist. Joint meeting with the Rochester Engineering society.

Seattle.—January 16, 1917, Arctic Building: Paper: "The Harbor Development of the Port Commission, with Particular Reference to the Electrical Features" by R. N. Allen. Attendance 37.

February 20, 1917, Arctic Building. Illustrated lecture by Mr. O. L. Coward on "Electric Traction". Attendance 51.

Spokane.—February 16, 1917, Council Chamber, City Hall. Paper: "Concrete Reinforcement of Poles" by George Harding. Motion picture "The King of the Rails". Attendance 62.

February 21, 1917, Spokane Hotel. By invitation at the Northwestern Mining Men's Convention. Papers: (1) "Application of Electricity in Mining" by E. M. Murphy; (2) "Mining in Alaska" by F. W. Isham. Motion picture of "The Building of the Transcontinental Telephone Line".

Digitized by Google

St. Louis.—February 28, 1917, Engineers Club. Address by Mr. Harold B. Shaw on "Rates for Electricity Supply". Attendance 117.

Toledo.—March 7, 1917, Toledo Commerce Club. Address by Mr. E. B. Thurston on "Electric Elevator Efficiency". Attendance 19.

Toronto.—February 16, 1917, Engineers Club. Address by Mr. C. E. Davies on "Automatic Telegraphy" followed by inspection of the exchange of the Great North Western Telegraph Company where the automatic machines were shown in actual operation. Attendance 40.

March 2, 1917, Engineers Club. Inspection trip to the Adelaide Exchange of the Bell Telephone Company. Attendance 40.

PAST BRANCH MEETINGS

University of Arkansas.—February 19, 1917. Papers: (1) "A Description of the Anaconda Copper Mines"; (2) "The Development and Future of Electric Propulsion of Ships". Attendance 18.

Armour Institute.—February 28, 1917. Paper: "Lake Spaulding Hydro-electric Developement" by Stanley Dean and E. H. Freeman. Paper was illustrated with lantern slides. Attendance 41.

March 6, 1917. Paper: "Organization of the Western Union Telegraph Company" by W. W. Drew. Attendance 36.

Polytechnic Institute of Brooklyn.—Rialto Theatre. Inspection of lighting system of Rialto Theatre, Times Square New York. Attendance 20.

University of California.—February 1, 1917, Berkeley. Addresses by Messrs. Rosenblatt and Dusenbery on "Electricity in Magic and Stage Illusions". Attendance 18.

February 14, 1917, Berkeley. Address by Mr. Pomeroy on "The Effect of Capacity and Inductance on Alternating Current Circuits". Attendance 19.

Carnegie Institute of Technology.—February 14, 1917. Papers: (1) "The New Steam Power Plant of the Buffalo Electric Company" by A. L. Morley; (2) "The Locomotive Works of the General Electric Company at Erie" by T. I. Lawson; (3) "The Niagara Falls Power Plant" by T. B. Blalock; (4) "The Hydraulic Power Company Plant at Niagara" by J. J. Kennedy; (5) "The U. S. Light and Heating Company Works" by L. H. Hale; (6) "Non-technical Features of the Inspection Trip" by C. H. Kindl. Attendance 30.

Colorado State Agricultural College.—February 26, 1917, Main Building. Illustrated address by Mr. Richards on "The Electrification of the Panama Canal".

March 12, 1917, Electrical Hall. Address by Mr. Knapp on "The Uses of Electricity in Modern Warfare".

Georgia School of Technology.—February 20, 1917, Regent Theatre. Moving picture of the National Tube Company" entitled "From Ore to Finished Product" with explanatory remarks by Mr. Wilson. Attendance 133.

Highland Park College.—February 7, 1917, Electrical Engineering Laboratory. Paper: "Central Station Steam Heating" by H. W. Garner. Attendance 89.

March 7, 1917, Electrical Engineering Laboratory. Paper: "History, Development and Manufacture of the Incandescent Lamp" by N. W. Longrove. Attendance 20.

Iowa State College.—February 14, 1917. Address by Mr. J. M. Drabelle on "Recent Developments in High-Tension Transmission". Attendance 80.

February 28, 1917. Paper: "The Opportunities of Technical Graduates in Public Utility Corporations" by F. S. Dewey. Attendance 64.

University of Iowa.—January 16, 1917, Physics Building. Paper: "The Effect of the European War on the Manufacture of Telephones" by E. Imhoff.

University of Kansas.—February 21, 1917, Marvin Hall. Addresses as follows: (1) "The Owen Magnetic Car" by C. R. Copp; (2) "The Manufacture

Digitized by Google

of Electric Auto Headlights" by A. R. Burt; (3) "Storage Battery Service Stations" by N. Beusheidt. Attendance 35.

February 28, 1917, Marvin Hall. Addresses as follows: (1) "Thesis Report on Car Heating" by C. E. Kietzman and S. Kruse; (2) "Interurban Substation at Kent, Kansas" by R. W. Warner; (3) "Street Railway Track Reconstruction" by C. A. Keener. Attendance 38.

Lafayette College.—February 24, 1917. Papers: (1) "Rail Materials and Shapes"; (2) "The Grounded Neutral, When and Why". Attendance 18.

March 5, 1917. Papers: (1) "Frequency Changers"; (2) "Methods of Obtaining Single-Phase Loads from Polyphase Lines". Attendance 17.

March 12, 1917. Papers: (1) "Protection of Transmission Lines by Means of Relays"; (2) "The Maximum Demand Meter". Attendance 16.

Lehigh University.—March 1, 1917, Physics Building. Papers: (1) "Electrolytic Copper" by L. C. Kramer; (2) "Electric Furnaces in the Steel Industry" by S. H. Auerbacker. Attendance 45.

University of Minnesota.—February 21, 1917, Biology Building. Illustrated lectures by Messrs. G. H. Pfeif and R. Goetzenberger on "High-Speed Motors". Motion pictures showing the construction of Curtis turbines. Attendance 55.

March 8, 1917, Engineering Auditorium. Lecture by Mr. L. T. Hill on "Some Telephone Problems and the Organization of the Bell System". Attendance 20.

University of Missouri.—February 19, 1917, Engineering Building. Illustrated lecture by Mr. G. A. Delaney on "Magnetization Curves". Attendance 20.

March 5, 1917, Engineering Building. Paper: "Industrial Application of Electric Motors" by M. P. Weinbach. Attendance 14.

University of Nebraska.—March 7, 1917. Papers: (1) "Plans and Specifications on Transmission Lines" by Mr. Hlava; (2) "The Human Side of Transmission Line Construction" by Mr. Wagner; (3) "The Costs of Transmission Lines" by Mr. Glasser. Attendance 18.

University of North Carolina.—March 1, 1917. Paper: "Single-Phase Traction" by A. C. Forney. Attendance 16.

March 8, 1917. Paper: "Economic Aspects of Railway Electrification" by E. J. O'Brien. Attendance 7.

March 15, 1917. Paper: "Development of High-Voltage Transmission" by W. R. Harding. Attendance 11.

Norwich University.—March 8, 1917, Carnegie Hall. Paper: "Electric Propulsion of the U. S. Collier Jupiter" by E. B. Davison. Paper illustrated by lantern slides. Attendance 27.

Ohio Northern University.—March 14, 1917, Dukes Memorial. Addresses as follows: "Manufacture of Incandescent Lamps" by H. A. Peterman; "The Modern Aeroplane" by F. W. Molitor. Attendance 37.

Ohio State University.—February 23, 1917, Robinson Laboratory. Lecture by Mr. H. R. Allensworth on "The Making of an Inventory of a Large Electric Utility". Attendance 20.

March 9, 1917, Robinson Laboratory. Address by Mr. W. H. Sawyer on "Public Utilities". Attendance 25.

Pennsylvania State College.—February 28, 1917. Addresses as follows: "Electrolytic Lightning Arrester" by Mr. Mickey; "Railway Electrification" by Mr. Malloy. Attendance 35.

University of Pittsburgh.—February 20, 1917, Thaw Hall. Address by Mr. J. H. Mahaffey on "The Construction and Uses of the Edison Storage Battery". Attendance 19.

March 6, 1917, Thaw Hall. Address by Mr. J. W. Welch on "Traffic Problems in Pittsburgh. Attendance 28.

Purdue University.—February 27, 1917, Electrical Building. Paper: "The Development of Radio Telegraphic Communication by F. F. Hamilton. Attendance 110.

March 1, 1917, Electrical Building. Address by J. B. Feder on "Electrifica-

Digitized by Google

tion of Railroads". Motion pictures "The King of the Rails". Attendance 350.

Rensselaer Polytechnic Institute.—February 26, 1917, Sage Laboratory. Address by Mr. A. H. Armstrong on "The Electrification of the Chicago, Milwaukee and St. Paul Railroad". Address was illustrated by lantern slides and motion pictures. Attendance 155.

Syracuse University.—March 1, 1917. Digest of article on "Relay Protective Systems", given by Mr. D. N. Epstein. Attendance 16.

March 8, 1917. Address by Mr. W. D. Pomeroy on "Telephone Systems and Operation". Attendance 17.

March 15, 1917. Address by Mr. H. R. Klumbach on "Electrification of the West Shore Railroad". Attendance 16.

University of Texas.—February 26, 1917. Papers: (1) "Historical Sketch of the Development of the Steam Boiler" by A. Naetes; (2) "Electricity on Shipboard" by A. E. Finlay. Attendance 18.

Virginia Polytechnic Institute.—February 27, 1917. Illustrated lecture on "The Evolution of the Motive Power for Ships". Attendance 51.

March 8, 1917, Science Hall. Lecture by Mr. John G. Henninger on "The Different Kinds of Lamps—The Way They are Made". Attendance 55.

University of Virginia.—February 21, 1917, Engineering Building. Papers: (1) "Ford Power Plant" by Prof. Hancock; (2) "Wireless Stations and Elementary Principles of Operation" by T. R. Bunting and R. G. Wolcott. Attendance 40.

Washington University.—February 21, Cupples Hall. Lecture by Dean A. S. Langsdorf on "The Cause and Effect of Lightning". Attendance 39.

University of Washington.—January 13, 1917, Forestry Hall. Address by Mr. S. C. Lindsay on "Some Recent Engineering Problems and Their Solution". Attendance 33.

March 13, Forestry Hall. Paper: "Telephone Line Distribution" by W. H. Curran. Attendance 12.

Washington State College.—January 19, 1917. Address by Prof. Buerstatte on "My Experience as a Special Railroad Apprentice". Election of officers as follows; president, D. M. Alexander; vice-president, B. Benz; secretary, C. W. Cutler; treasurer, S. E. Stites. Attendance 30.

February 16, 1917. Address by Prof. Snyder on "The Cement Dam and the Problems to be Overcome in Its Construction". Attendance 28.

Worcester Polytechnic Institute.—February 23, 1917, Electrical Engineering Building. Paper: "Grounding of Alternating-Current Secondary Distribution Systems" by W. H. Blood Jr. Attendance 65.

March 16, 1917, Electrical Engineering Building. Paper: "Traffic Problems of a Large Urban Railway" by Edward Dana. Attendance 40.

Yale University.—March 9, 1917. Illustrated lecture by Mr. C. C. Elwell on "Accident Prevention". Attendance 40.

MEMBERS ELECTED MARCH 9, 1917

FINN, JAMES R., Chief Electrician, Cutler-Hammer Mfg. Co.; res., 1913 Cold Spring Ave., Milwaukee, Wis.

INGLIS, JOSEPH JEFFREY, Chief Electrical Engineer, Dalzell Steel and Iron Works; res., "Heimat", Adele St., Motherwell, Scotland.

MAHONEY, JOSEPH NATHANIEL, Engineer in Charge, Switch & Circuit Breaker Section, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

MEYER, WILLIAM E., Assistant Engineer, Public Service Electric Co., Newark; res., 55 Hampton Place, Nutley, N. J.

MUNDO, CHARLES J., Salesman, General Electric Co., 1314 Oliver Bldg.; res., 5733 Forbes St., Pittsburgh, Pa.

NEELY, FREDERICK L., Engineer, Light, Heat & Power Div., E. I. du Pont de Nemours & Co.; res., 916 Delaware Ave., Wilmington, Del.

Digitized by Google

RILEY, LYNN GARDINER, Assistant to Control Section Engineer, Railway Engineering Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh, Pa.

*SHUTE, EMMETT RAY, Assistant Traffic Engineer, Western Union Telegraph Co., 195 Broadway, New York; res., Floral Park, N. Y.

STEWART, FENWICK JOSEPH THRASHER, Superintendent, Bureau of Surveys, N. Y. Board of Fire Underwriters, 123 William St., New York, N. Y.

SWAN, SAMUEL BOSWORTH, Electrical Engineer, Narragansett ElectricLighting Co., Providence; res., Barrington, R. I.

THOMPSON, GEORGE GARRETT, Electrical Engineer, Cutler-Hammer Mfg. Co.; res., 305 22nd St., Milwaukee, Wis.

WERTH, JAMES ROBERT, Electrical Engineer, Lighting Dept., General Electric Co.; res., 29A Front St., Schenectady, N. Y.

*Former enrolled Student.

ASSOCIATES RE-ELECTED MARCH 9, 1917

HUMISTON, JOHN M., Facilities Engineer, Chicago Telephone Co., 212 W. Washington St., Chicago, Ill.

JOHNSTON, WILLIAM DEMOREST, Transmission Engineer, Central District Telephone Co.; res., 1697 Suburban Ave., Pittsburgh, Pa.

JOYNER, A. H. W., Manager, A. H. Winter Joyner, Ltd., 100 Wellington St. West; res., 293 Huron St., Toronto, Ont.

LYNDON, LAMAR, Consulting Engineer, 30 Church St., New York, N. Y.

TOWNSEND, F. P., Sales Engineer, Cutler-Hammer Mfg. Co.; res., 528 Stowell Ave., Milwaukee, Wis.

WOOLFENDEN, HENRY LUMSDEN, District Manager, Allis-Chalmers Mfg. Co., Denver, Colo.

MEMBER RE-ELECTED MARCH 9, 1917

STORRS, HARRY A., Department of the Interior, U. S. Indian Service, Tucson, Ariz.

ASSOCIATES ELECTED MARCH 9, 1917

ALGER, PHILIP LANGDON, Research Assistant in Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.; res., 34 Southgate Ave., Annapolis, Md.

*ALLCUTT, CHESTER T., Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 500 Todd St., Wilkinsburg, Pa.

ASHER, LEON, Operator, Utah Power & Light Co., Oneida Station, Preston, Idaho.

ATWOOD, F. R., Engineer, Illinois Div., Central Union Telephone Co.; res., 1216 So. 7th St., Springfield, Ill.

BAILEY, R. S., Electrical Engineer, Utah Power & Light Co.; res., 69 N. State, Salt Lake City, Utah.

*BEATTY, LEWIS BONSELL, Asst. Engineer, Station Construction Dept., Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

BEYER, W. WILSON, Designing Engineer, Philadelphia Electric Co., Philadelphia; res., 520 Astor St., Norristown, Pa.

BIESGEN, AUGUST, Electrical Draftsman, Cutler-Hammer Mfg. Co.; res., 495 16th St., Milwaukee, Wis.

*BILLINGSLEY, CLIFFORD HUTCHINGS, Engineer, Interstate Light & Power Co., Galena, Ill.

BLACKWOOD, WILLIAM CUTLER, Electrical Engineer, N. Y. & Queens Electric Light & Power Co., Long Island City; res., 25 25th St., Elmhurst, L. I., N. Y.

BRATE, CHARLES FRANCIS, Engineering Dept., Aluminum Co. of America, 2402 Oliver Bldg., Pittsburgh, Pa.

*BROWN, HENRY B., Automatic Tel. Switchboard Installer, Automatic Electric Co., Edmonton, Alta., Canada.

Digitized by Google

*BROWN, RICHARD EDMUND, Instructor in Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.

BURGGRAF, KARL HENRY, Apprentice, Lincoln Electric Co., Cleveland; res., Euclid, O.

BURNAP, ROBERT SAMUEL, Research Assistant in Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

CALVERT, HAROLD, Electrical Engineer, Philadelphia Electric Co., 226 11th St., Philadelphia; res., 323 S. Chester Rd., Swarthmore, Pa.

CANTLIN, A. H. S., Vice-President and Manager, Lehigh Valley Light & Power Co., 542 Hamilton St.; res., 125 N. 4th St., Allentown, Pa.

COE, EDWARD HUMPHREY, Sales Engineer, Colorado Power Co., 828 Symes Bldg.; res., 360 Humboldt St., Denver, Colo.

CONNELL, BENNETT ROBERT, Engineer, Power & Mining Engineering Dept., General Electric Co.; res., 417 Becker St., Schenectady, N. Y.

COSTELLO, WILLIAM H., Engineer, Cutler-Hammer Mfg. Co.; res., 114 34th St., Milwaukee, Wis.

COZAD, WALTER FRANKLIN, General Traffic Superintendent, Mountain States Tel. & Tel. Co., 1421 Champa St.; res., 1640 Madison St., Denver, Colo.

CUERDON, T. JOSEPH, Chief Operator, Hydro-electric Plant, Cohoes Co., Cohoes; res., 434 6th Ave. N., Troy, N. Y.

DE MUTH, FRED A., Testing Engineer, Sanitary District of Chicago, 31st & Western Ave.; res., 2840 S. St. Louis Ave., Chicago, Ill.

DOUGHERTY, JOHN JOSEPH, Assistant System Operator, Duquesne Light Co.; res., 3406 Ward St., Pittsburgh, Pa.

*DREW, WALTER WHITE, Acting Div. Traffic Engineer, Western Union Telegraph Co., 111 W. Jackson Blvd.; res., 6243 St. Lawrence Ave., Chicago, Ill.

*DU VALL, W. CLINTON, Instructor in Electrical Engineering, University of Pennsylvania; res., 5506 Upland St., Philadelphia, Pa.

EASLEY, CARY BRECKINRIDGE, Assistant Electrical Engineer, Associated Factory Mutual Fire Insurance Co's., 31 Milk St.; res., 336 Commonwealth Ave., Boston, Mass.

ENGLAND, PHILLIP D., Electrical Engineer, National Electric & Engineering Co. Ltd.; res., Devenport, Auckland, New Zealand.

ENSWEILER, EDWARD JOSEPH, Electrical Testing, Cutler-Hammer Mfg. Co.; res., 865 25th St., Milwaukee, Wis.

FLEMING, DAVID B., Engineer, Ontario Hydroelectric Power Commission; res., 470 Euclid Ave., Toronto, Ontario.

FORD, WILLIAM ARTHUR, Electrical Engineer, Rome Railway & Light Co., Rome, Ga.

FOSTER, JOSEPH TURNER, Engineering Assistant Public Service Electric Co., Newark; res., 107 Duncan Ave., Jersey City, N. J.

FOSTER, WILLIAM, Superintendent, Aerial Lines, Philadelphia Electric Co.; res., 3218 Turner St., Philadelphia, Pa.

FOX, ERNEST ALLEN, Assistant to Superintendent of Electric Dept., Charleston Consolidated Railway & Lighting Co., Charleston, S. C.

*FRIEDE, HENRY, Valuation Engineer, Toledo Railways & Light Co.; res., 103 Carleton Apts., Toledo, O.

GASKELL, SAMUEL ATHERTON, Managing Director, Lancashire Dynamo & Motor Co., 107 Duke St.; res., 175 Scarborough Rd., Toronto, Ont.

GENOR, ANDREW CLIFFORD, Draftsman, Duquesne Light Co.; res., 219 Kennedy Ave., Pittsburgh, Pa.

GIBBONY, ALVIN PERCY, Testing Transformers, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 600 Rebecca Ave., Wilkinsburg, Pa.

*GOLDTHWAITE, GEORGE EDGAR, Associate Editor, *Railway Electrical Engineer*; res., 140 W. 75th St., New York, N. Y.

Digitized by Google

GORMAN, EDWARD ROWELL, Superintendent and Manager, Connecticut Co., Groton, Conn.

GRAH, MILWARD E., Engineering Dept., Toledo Railways & Light Co.; res., Marengo St., River Rd., Toledo, O.

HARVEY, JOHN WILLIAM, Assistant Professor of Electrical Engineering, University of Maine, Orono, Me.

HEATH, LEWIS ARTHUR, Engineer, General Electric Co., New York, N. Y.; res., 16 Livingston Ave., New Brunswick, N. J.

HEUER, REINHOLD H., Engineer, Cutler-Hammer Mfg. Co.; res., 381 3rd Ave., Milwaukee, Wis.

HOLLAND, W. E., Salesman, Dallas Office, Westinghouse Electric & Mfg. Co.; res., 809 N. Pearl, Dallas, Tex.

HOLZBERGER, GEORGE R., Electrician, Electrical Construction Dept., Pacific Gas & Electric Co., San Francisco; res., 461 34th St., Oakland, Cal.

HOWARD, ROBERT BURNHAM, Field Engineer, Philadelphia Electric Co.; res., 4907 Walnut St., Philadelphia, Pa.

HOWE, WILLIAM MASON, Experimental Tester, General Electric Co., West Lynn; res., 15 Newhall St., Lynn, Mass.

HUEY, CLARENCE, Chief Sub-Inspector, Electrical, New York Navy Yard; res., 295 Schermerhorn St., Brooklyn, N. Y.

JEFFERS, GEORGE LINWOOD, Electrical Salesman, Westinghouse Electric & Mfg. Co., E Pittsburgh; res., 205 Franklin Ave., Wilkinsburg, Pa.

JERSEY, CHESTER CHARLES, Lieutenant, U. S. Navy, Navy Dept., Washington, D. C.

JOHNSON, ARTHUR F., Draftsman, Utah Power & Light Co.; res., 641 So. 4th East St., Salt Lake City, Utah.

*KAZDA, CHARLES BOHUMEL, Instructor, Employees Courses, Chicago Central Station Institute; res., 2601 S. Trumbull Ave., Chicago, Ill.

KEELER, FRANK S., Cadet Engineer, New York Edison Co., New York; res., 247 Cumberland St., Brooklyn, N. Y.

KELLEY, CHESTER A., Operator, Utah Power & Light Co., Oneida Power Plant, Preston; res., Oneida, Idaho.

*KERR, HENRY H., Cadet Engineer, Trumbull Public Service Co., Warren, Ohio.

KNIPFER, FREDERIC C., Industrial Control Engineering Dept., General Electric Co.; res., 3 Cornelius Ave., Schenectady N. Y.

*KURTZ, WILLIAM OVERTON, Engineer, New York Telephone Co., 15 Dey St., New York, N. Y.; res., 123 Gordonhurst Ave., Upper Montclair, N. J.

LAGERSTROM, DAVID R., Assistant Engineer, Dept. of Light, Heat & Power, General Electric Co., Schenectady, N. Y.

LAROS, RUSSELL K., Power Engineer; Lehigh Valley Light & Power Co., res., Y. M. C. A. Bldg., Allentown, Pa.

LEE, HARRY R., Chief Draftsman, Illinois Div., Central Union Telephone Co., 626 Reisch Bldg.; res., 615 S. Park Ave., Springfield, Ill.

*LEECH, ROBERT W., Sales Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 301 Gray Apts., Wilkinsburg, Pa.

LEIBOLD, CARRIN A., Electrical Engineer, Berks Engineering Co.; res., 234 S. Third St., Reading, Pa.

LESTER, JOHN RUSH, Instructor in Mechanical Arts and Mechanical Drawing, Ensley High School, Ensley, Ala.

LOCKYER, R. H. N., In charge Power Plant, Consolidated Mining & Smelting Co., Trail, B. C.

LOGAN, ROBERT SETON, Electrical Draughtsman, Northern Electric Co.; res., 821 Grosvenor Ave., Montreal, Que.

LUPINSKI, HUGO HOUGHTON, Salesman, Westinghouse Electric & Mfg. Co., 165 Broadway, New York; res., Liberty, N. Y.

*MADDEN, MILTON FINNEY, Assistant with Chief Engineer, Mechanical Dept., Santa Fe Ry., Grand Canyon, Ariz.

Digitized by Google

MARR, GEORGE M., Electrical Dept., Navy Yard; res., 896 Nostrand Ave. Brooklyn, N. Y.

MATTHEWS, FRANK PERCY, Electrical Superintendent, Dryden Timber & Power Co. Ltd., Dryden, Ont.

MAXWELL, GILES SANFORD, Engineer, Railway Dept., General Electric Co.; res., 20 N. Church St., Schenectady, N. Y.

MCKEE, GROSVENOR STEWART, Assistant Yard Engineer, American Gas & Electric Co., Windsor Power Station, Windsor, W. Va.

MICKLER, CYRIL FRANCIS, Construction Foreman, General Electric Co., Atlanta; res., 26 E. 41st St., Savannah, Ga.

MILLAR, EDWARD A., Jr., Electrical Engineer, Foundation Co., New York, N. Y.; res., 818 So. 49th St., Philadelphia, Pa.

MILLER, WILLIAM HEYER, Test Foreman, Burke Electric Co.; res., 813 Cherry St., Erie, Pa.

MOORE, ETHELBERT ERNEST, Electrical Engineer, Hydro-Electric Power Commission, 190 University Ave.; res., 82 Fermanagh Ave., Toronto, Ont.

*MORGAN, NEIL L., 395 Durocher St., Montreal, Que.

MOYER, MELBOURNE SPEER, Certified Public Accountant, 8 South Dearborn St.; res., 5221 Woodlawn Ave., Chicago, Ill.

MUNNINGHOFF, AUGUST, Foreman, Testing Dept., Cutler-Hammer Mfg. Co.; res., 1351 15th St., Milwaukee, Wis.

NABESHIMA, UHACHI, 175 Fuller St., Brookline, Mass.

OBERSCHMIDT, FRED HERMAN, Engineer, Cutler-Hammer Mfg. Co.; res., 254 16th St., Milwaukee, Wis.

ORWIG, CLYDE EMANUEL, Assistant to Engineer, General Electric Co., 1302 Oliver Bldg.; res., 7831 Susquehanna St., Pittsburgh, Pa.

OWEN, FRED B., In charge of Standardizing Dept., General Electric Co.; res., 3907 Fairfield Ave., Fort Wayne, Ind.

OWEN, WILLIAM BRADFORD, JR., Charge Meter and Wholesale Power Rate Dept., Wilkes Barre Co., 133 N. Washington St., Wilkes Barre, Pa.

PANTON, HARRISON DOUGLAS, Engineering Office, Carolina Power & Light Co.; res., 109 E. Lane St., Raleigh, N. C.

PAYTON, MAURICE JOSHUA, Standardizing Dept., General Electric Co.; res., 2726 S. Lafayette St., Ft. Wayne, Ind.

PIERCE, THOMPSON BAIRD, Construction Engineering, Appalachian Power Co.; res., 107 Ramsey St., Bluefield, W. Va.

*PLASS, CHARLES WEBSTER, Instructor in Electrical Engineering, University of Pennsylvania; res., Chew and Chelten Ave., Philadelphia, Pa.

*PUBLOW, CEDRIC FRANKLIN, Designing Draftsman, Hydro-Electric Power Commission; res., 305 Gladstone Ave., Toronto, Ont.

RALSTON, FARLEY C., District Substation Foreman, Philadelphia Electric Co., Ogontz; res., 1941 Laveer St., Philadelphia, Pa.

RAYNOR, KENNETH MILLS, Foreman, Electrical Dept., Bethlehem Steel Co., So. Bethlehem; res., University Club, Bethlehem, Pa.

*REES, LOUIS DUBOIS, Engineering Apprentice, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., Gray Apts., Wilkinsburg, Pa.

ROBERTSON, ARTHUR STUART, Hydro-Electric Power Commission; res., 34 Kenneth Ave., Toronto, Ont.

RUSSELL, EDWARD GORDON, Testing Engineer, Commonwealth Edison Co., 28 N. Market St.; res., 958 Lorel Ave., Chicago, Ill.

RUSSELL, FRANK J., Engineering Dept., Cutler-Hammer Mfg. Co., Milwaukee; res., 247 Johnson Ave., Wauwatosa, Wis.

RUSSELL, WITMER, Cadet Engineer, New York Edison Co.; res., 666 W. 207th St., New York, N. Y.

RUST, ELMER P., Testing Engineer, C. H. Wheeler Mfg. Co.; res., 4733 N. Marvine St., Philadelphia, Pa.

Digitized by Google

SAMUELSON, JOHN AUGUST, Superintendent of Light and Power, Russell Light & Power Co., Russell, Kans.

*SANFORD, JAMES HAROLD, Estimating Bureau, Philadelphia Electric Co., 919 Walnut St., Philadelphia, Pa.

SCHNEIDER, FREDERICK WILLIAM, Senior Inspector of Electric Conductors, City of New York; res., 2121 Arthur Ave., New York, N. Y.

SCHWARZE, FRED, Electrical Engineer, Pfister & Vogel Leather Co.; res., 1214 12th St., Milwaukee, Wis.

*SCUTARI, CRISPIN, Engineer, 473 Broadway, New York; res., 955 68th St., Brooklyn, N. Y.

SEABROOK, W. CLARENCE, Construction Div., General Electric Co., Philadelphia; res., Fairfield, Pa.

SEIBERT, WILLIAM J., Assistant Foreman Electrical Maintenance, General Electric Co.; res., 212 Holland St., Erie, Pa.

SHAKIN, VICTOR, Junior Electrical Engineer, Public Service Commission, 1st District, 2450 Equitable Bldg.; res., 815 Cauldwell Ave., New York, N. Y.

SMOOT, WALTER D., Power Superintendent, Willard Storage Battery Co.; res., 719 E. 118th St., Cleveland, O.

SNIDER, GEORGE E., Distribution Engineer, Toledo Railways & Light Co.; res., 933 E. Bancroft, Toledo, O.

SPENCE, JAMES, 2nd Lieut. R. E., 3/2 London Divisional Signal Co. R. E., Signal Depot, Hitchin, Herts, England; res., 21 Burnbank Gardens, Glasgow, Scotland.

SRINIVASAYENGAR, V. K., Electric Telegraph Inspector, Madras & Southern Mahratta Railway, Hubli, India.

STEARN, FRANKLIN ANDRUS, Telephone Engineer, Western Electric Co., New York, N. Y.; res., 197 E. 31st St., Paterson, N. J.

STEPHENSON, GORDON BENNETT, Electrical Tester, Cutler-Hammer Mfg. Co., Milwaukee; res., 118 50th St., Wauwatosa, Wis.

STEWART, HAROLD CHARLES, Transformer Engineering Dept., General Electric Co.; res., 185 Wahconah St., Pittsfield, Mass.

STODDART, HERBERT GEORGE, Chief Electrician, Rubberset Co., Newark; res., 441 Norwood St., E. Orange, N. J.

STOETZEL, DAVID, JR., Industrial Control Engineering Dept., General Electric Co.; res., 13 Snowden Ave., Schenectady, N. Y.

STORY, EDWARD CARLETON, D. C. & WM. B. JACKSON, 248 Boylston St., Boston; res., 26 Metropolitan Ave., Roslindale, Mass.

SWARTZ, CHARLES AUGUSTUS, Salesman, Ludwig Hommel & Co., Pittsburgh; res., 907 Adelaide St. E., East Pittsburgh, Pa.

TAUSSIG, WARREN ALLEN, Engineer, Wagner Electrical Mfg. Co., St. Louis; res., 549 E. Main St., Kirkwood, Mo.

TETELMAN, LOUIS LEO, JR., Electrical Engineer, Public Service Commission; res., 475 E. 145th St., New York, N. Y.

THAYER, CHARLES SANFORD, Electrical Superintendent, Aluminum Co. of America, Massena, N. Y.

THOMPSON, CHARLES MILLS, Jr., Station Construction Dept., Philadelphia Electric Co., Philadelphia; res., 336 W. Duval St., Germantown, Pa.

THORN, CHARLES S., Engineering Dept., Philadelphia Electric Co., Philadelphia; res., Crum Lynne, Pa.

THORNBURG, CARL A., Chief Engineer, Kingsport Power Corp., Kingsport, Tenn.

TONGE, JAMES LOMAS, Assistant to the Electrical Engineer, D. & W. Fuse Co., Providence, R. I.

TOURTELLOTT, ARTHUR, Electrician, Power Station, General Electric Co.; res., 159 E. 11th St., Erie, Pa.

TOWNSEND, CHARLES PINCKNEY, Underground Dept., Georgia Railway & Power Co. Electric & Gas Bldg.; res., 83 Park St., Atlanta, Ga.

Digitized by Google

TRUEBLOOD, HOWARD MOFFITT, Assistant Professor of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.

*VAUTROT, LOUIS RICHARD, Electrical Engineer, Cutler-Hammer Mfg. Co.; res., 291 22nd St., Milwaukee, Wis.

WADE, HENRY N., Development Engineer, Cutler-Hammer Mfg. Co.; res., 386 22nd St., Milwaukee, Wis.

*WEBBER, LEON HUBERT, Electrical Dept., N. Y. C. R. R., Room 4849, Grand Central Terminal, New York.

WEBSTER, JAMES CLARENCE, Chemical Engineer, National Carbon Co.; res., 14304 Detroit Ave., Cleveland, O.

WELSH, RAYMOND WILMER, Engineering Dept., Bell Telephone Co. of Pennsylvania; res., 1534 Diamond St., Philadelphia, Pa.

WHITBECK, WILLIAM LEONARD, Head Tester, York Exchange, Mountain States Tel. & Tel. Co.; res., 1221 Vine St., Denver, Colo.

WIGHTMAN, JAMES WESLEY, Sales Engineer, General Electric Co., Cincinnati, O.; res., Pineville, Ky.

WILLIAMS, SAMUEL S., Chief Engineer of Power Stations, Roanoke Railway & Electric Co., Roanoke, Va.

*WOOD, RAY ALLEN, Sales Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 7721 Brashear St., Pittsburgh, Pa.

WOOD, WILLIAM MUSGRAVE, Inspecting Engineer's Staff, United Gas Improvement Co., 1401 Arch St., Philadelphia, Pa.

YOKURA, M., Engineering Commander, Imperial Japanese Navy, Room 1513, 25 Madison Ave., New York, N. Y.

*ZIMMERMAN, WILLIAM J., Cadet Engineer, Philadelphia Electric Co.; res., 2241 N. 18th St., Philadelphia, Pa.

ZOLLER, MARTIN LEOPOLD, Electrician, Natomas Consolidated of California; res., 2319 P St., Sacramento, Cal.

ZORNIG, HERMANN HEINRICH, 1st Lieutenant, Ordnance Dept., U. S. Army, Watertown Arsenal, Watertown; res., 49 Judkins St., Newtonville, Mass.

Total 140.

*Former enrolled Students.

RECOMMENDED FOR TRANSFER

The Board of Examiners recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

Recommended at meeting March 5, 1917.

To Grade of Fellow

HEWLETT, E. M., Engineer of Switchboard Dept., General Electric Co., Schenectady, N. Y.

LYNDON, LAMAR, Consulting Engineer, New York, N. Y

YARDLEY, J. L. M., Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

To Grade of Member

LISTON, JOHN, Technical Writer and Lecturer, Publication Bureau, General Electric Co., Schenectady, N. Y.

Recommended at Meeting March 19, 1917.

To Grade of Member

ATKISSON, E. J., Captain, Corps of Engineers, Assistant Superintendent, Gatun Locks, Gatun, C. Z.

Recommended at Meeting March 22, 1917.

To Grade of Member

BLACKBURN, LEONARD A., Electrical Engineer, E. I. du Pont de Nemours & Co., City Point, Va.

CARR, WALTER DE LANCEY, Assistant to Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

HARVEY, GILBERT A., Electrical Engineer, Philadelphia Rapid Transit Co., Philadelphia, Pa.

JAMIESON, BERTRAND C., Engineer of Inside Plant, Commonwealth Edison Co., Chicago, Ill.

LIVERSIDGE, HORACE P., Operating Engineer, Philadelphia Electric Co., Philadelphia, Pa.

Digitized by Google

LYLE, FREDERICK W., Electrical Engineer, Research Laboratory, General Electric Co., Lynn, Mass.

SCOTT, EDGAR G., Superintendent of Power and Repairs, Ludlow Manufacturing Associates, Ludlow, Mass.

TRANSFERRED TO THE GRADE OF FELLOW MARCH 9, 1917

KNIGHT, GEORGE LAURENCE, Designing Engineer, Edison Electric Illuminating Co. of Brooklyn, Brooklyn, N. Y.

PEIRCE, ALBERT EDWIN, Vice-President and General Manager, Wisconsin-Minnesota Power & Light Co., Eau Claire, Wis.

TESLA, NIKOLA, Inventor, New York, N. Y.

TRANSFERRED TO THE GRADE OF MEMBER MARCH 9, 1917

KEELER, N. B., Junior Electrical Engineer, Fort Drum, P. I.

LINDSTROM, GUSTAV, Chief Engineer and Secretary, Electric Products Co., Cleveland, O.

MORROW, L. W. W., Associate Professor of Electrical Engineering, University of Oklahoma, Norman, Okla.

WOOLFENDEN, H. L., District Manager, Allis-Chalmers Mfg. Co., Denver, Colo.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before April 30, 1917.

Ambuhl, F. F., Toronto, Ont.
Armstrong, H. H., Detroit Mich.
Baker, L. A., E. Pittsburgh, Pa.
Baker, R., New York, N. Y.
Ballard, B. J. (Member), Cleveland, O.
Bartlett, A. E., Schenectady, N. Y.
Bell, R. S., Toronto, Ont.
Bishop, E. A., Chicago, Ill.
Bodenbach, R. P., Milwaukee, Wis.
Bonham, L. D., Denver, Colo.
Bowditch, R., Indianapolis, Ind.
Brooke, B. F., Philadelphia, Pa.
Brown, C. G., Rochester, N. Y.
Burgess, H. O. Bangor, Me.
Carr, J. M., Detroit, Mich.
Catlin, J. P. (Member), Pittsfield, Mass.
Cavanagh, J. F. (Member), Meriden, Conn.
Clapp, D., Boston, Mass.
Clark, C. E., Los Angeles, Cal.
Clarke, C. F., Chicago, Ill.
Coleman, R. M. (Member), New York, N. Y.
Collins, J. L. (Member), Lowell, Mass.
Conner, G. C., Boston, Mass.
Cooper, S. C., New York, N. Y.
Dair, W. J. O., New York, N. Y.
Darlington, G. P., Philadelphia, Pa.
Davidson, J. E.,(Member),Omaha, Neb.
Day, R. F., Philadelphia, Pa.
de Clercq, A. G. (Member), Chicago, Ill.
Degenn, F. S., Detroit, Mich.
Dehn, G. R., Balboa, C. Z.
Dillon, T. H., Gatun, C. Z.
Downey, H. J., Detroit, Mich.
Downie, R. J., San Francisco, Cal.
Emerson, W. R., Muskogee, Okla.
Engelmann, J. L., Cleveland, O.
Ennis, W. H., New Orleans, La.
Eshbach, O. W., S. Bethlehem, Pa.
Fagge, W. E., Ardmore, Pa.
Fischer, C. W., Chicago, Ill.
Fisher, C. H., Wilmington, Del.
Forde, W. H., Boston, Mass.
Foster, O. L., Chicago, Ill.
Frank, M. H., Galesburg, Ill.
Gamper, G. H., Columbus, O.
Grant, L. H., Fresno, Cal.
Green, A. W. G., Montreal, Que.
Groenke, G. H., Balboa, C. Z.
Grubbs, C., Salinas, Cal.
Guy, W. T., Detroit, Mich.
Hansen, O., Chicago, Ill.
Haralson, N. M., Philadelphia, Pa.
Hazard, F. H., New York, N. Y.

Digitized by Google

Hayashi, Y., Sukegawa, Japan
Horr, E. N., Norristown, Pa.
Hunter, R. N. Cambridge, Mass.
Hutchins, W. J. M., St. Paul, Minn.
Irwin, A. E., Kimball, Neb.
Jacobs, E. H. (Fellow), Chicago, Ill.
Jacobs, G. A., Ft. Wayne, Ind.
Johnson, C. N., E. Pittsburgh, Pa.
Jones, W. E., Chicago, Ill.
Keeler, E. A., Philadelphia, Pa.
Keith, W. G. (Member), Chicago, Ill.
Keller, C. C., Chicago, Ill.
Kennedy, S. J., Oakland, Cal.
Key, H. W., Atlanta, Ga.
Kiser, A. B. (Member), Pittsburgh, Pa.
Knight, E. W., Columbus, O.
Kobak, E., New York, N. Y.
Kreis, J. G., New Haven, Conn.
Krogman, W. W., Chicago, Ill.
Krout, P. B., Philadelphia, Pa.
Kuhlman, E. (Member), Bay City, Mich.
Laing, N. B., Detroit, Mich.
Lauder, A. R. K., Schenectady, N. Y.
Lawson, J. S., New York, N. Y.
Leach, R. W. (Fellow), Boston, Mass.
Lewis, A. T., Philadelphia, Pa.
Lineberry, E., Newark, N. J.
Litchfield, R. B., New York, N. Y.
Lorenz, C. F., Cleveland, O.
Loy, J. M., Altoona, Pa.
Macdonald, W. G., Halifax, N. S.
Magnus, M. H., New York, N. Y.
Manwaring, M., Murray, Utah
Matson, C. H., Ft. Wayne, Ind.
McAllister, E. G., Philadelphia, Pa.
McCormick, R. J., Detroit Mich.
McKay, J. A., Badin, N. C.
McKee, M., Detroit, Mich.
McKinnell, D. M., New Bedford, Mass.
Mentzel, J. R., Oshkosh, Wis.
Merwin, F. R., New Orleans, La.
Mikaloff, J. P., Jr., Philadelphia, Pa.
Millar, H. H., Oakland, Cal.
Miller, H. P., Deadwood, S. D.
Mills, H. A., Denver, Colo.
Momberger, W. J., New York, N. Y.
Moore, E. B., Toledo, O.
Morgan, C. W., E. Pittsburgh, Pa.
Morrell, E. S., Philadelphia, Pa.
Munyan, E. A., City Point, Va.
Murray, A. H., Hamilton, Ont.
Norris, R. (Member), Philadelphia, Pa.
Ober, E. M., Vancouver, B. C.
Oster, E., Cincinnati, O.
Owens, G. M., Detroit, Mich.
Paszkiewicz, J. A. Chcago, Ill.
Perkins, H. R., Detroit, Mich.
Pihl, C. A., Pittsfield, Mass.
Porta, P. P., New York, N. Y.
Potts, H. B., Byesville, O.
Powell, E. J., Scranton, Pa.
Pratt, R. H. (Member), Atlanta, Ga.
Randolph, C. P. (Member), Pittsfield, Mass.
Reis, M. de O., Porto Alegre, Brazil
Robinson, G. N., Denver, Colo.
Ruegg, A., Milwaukee, Wis.
Salisbury, R. D., Denver, Colo.
Sandig, G. C., Denver, Colo.
Saperston, Q. N., Chicago, Ill.
Schirtzinger, L., Pittsburgh, Pa.
Siegfried, J. F. (Member), Easton, Pa.
Smith, H. J., San Francisco, Cal.
Smith, I. T., Jr., Brooklyn, N. Y.
Smith, R. C., Columbus, O.
Smith, R. E., Lowell, Mass.
Snyder, F. T. (Member), Chicago, Ill.
Steele, E. H., New Bedford, Mass.
Stinson, W. L., Newark, N. J.
Stokes, P. F., Cleveland, O.
Sullivan, J. S. B., Rochester, N. Y.
Taylor, A. J. T. (Member), Vancouver, B. C.
Thomas, R. S., Blackwell, Okla.
Todd, W., Omaha, Neb.
Toll, L. C., Cleveland, O.
Tonkin, J., Santiago, Chile
Torzillo, G.M. (Member), Springfield, Ill.
Tyson, E. H., Allentown, Pa.
Underhill, H. J., Virginia, Minn.
Walrath, A. J., Detroit, Mich.
Watson, J. N. M., New York, N. Y.
Webster, E., Lynn, Mass.
Weeman, H. F., Detroit, Mich.
Weir, R. P., Toronto, Ont.
White, E. J., Newark, N. J.
Winn, C. E., Chicago, Ill.
Wolfe, N. A., Schenectady, N. Y.
Woodfield, A. M., Philadelphia, Pa.
Wright, E. H., Chicago, Ill.
Wright, F. V. Z., Silverton, Colo.
Yokoyama, M., Tokio, Japan
Total 153.

Digitized by Google

STUDENTS ENROLLED MARCH 9, 1917

8799 McGanophy, J. B., Univ of Ark.
8800 Salter, W. F., N. Y. Elec. Sch.
8801 Mackey, B. R., Univ. of Penna.
8802 Campbell, F. W., Univ. of Penna.
8803 de Campos, A., Univ. of Penna.
8804 Stange, C.C., Tri-State Coll. of Eng.
8805 Hagen, R. C., Mont. State Coll.
8806 Worthen, C. H., Wash. State Coll.
8807 Cain, L. L., Tri-State Coll. Engg.
8808 Rudolph, H.L.; Ohio North. Univ.
8809 Anderson, W. F., Rensselaer Poly. Inst.
8810 de Andrade, J. M., Rensselaer Poly. Inst.
8811 Johnson, H. M., Rensselaer Poly. Inst.
8812 Mackenzie, J. V. A., Rensselaer Poly. Inst.
8813 Moore, R.P., Rensselaer Poly. Inst.
8814 Snyder, T.M., Rensselaer Poly. Inst.
8815 Townsend, W. R., Jr., Rensselaer Poly. Inst.
8816 White, H.A., Rensselaer Poly. Inst.
8817 Hass, J. S., Drexel Institute
8818 Wild, O. A., Drexel Institute
8819 Gray, S. M., Univ. of Penna.
8820 Lowry, R.C., A. & M. Coll. of Tex.
8821 Cohn, J. W., Armour Inst. Tech.
8822 Leonard, H. C., Union College
8823 Davis, L. I., Ala. Poly. Inst.
8824 Trawick, H. P., Ala. Poly. Inst.
8825 Warren, J. J., Ala. Poly. Inst.
8826 Jones, T. M., Ala. Poly. Inst.
8827 Jacobs, W. S., Ala. Poly. Inst.
8828 Simmons, F. K., Ala. Poly. Inst.
8829 Terrell, P. A., Ala. Poly. Inst.
8830 Protzky, J., Cooper Union
8831 Kodil, C. E., Los Angeles Poly. Junior College.
8832 Stacy, J.D., Rensselaer Poly. Inst.
8833 Singh, C., Univ. of Illinois
8834 Siegmund, H. O., Univ. of Ill.
8835 Newcomb, P. H., Yale Univ.
8836 Gower, A. W., Univ. of Wis.
8837 Kadlecek, E. M., Univ. of Neb.
8838 Godfrey, H. L., Univ. of Penna.
8839 Glanz, C. C., Univ. of Penna.
8840 Trimble, W. E., Bucknell Univ.
8841 Dixon, C. T., Univ. of Calif.
8842 Kupshas, A.C., Armour Inst. Tech.
8843 Zimmermann, A., Armour Inst. Tech.
8844 Taylor, W. J., N. Y. Elec. Sch.
8845 Arcaute, J. A., N. Y. Elec. Sch.
8846 Yost, C. H., Cornell Univ.
8847 Nankivell, F. J., Cornell Univ.
8848 Winn, G. P., Univ. of Ill.
8849 Butterfield, F. E., Univ. of Ill.
8850 Green, S. S., Purdue, Univ.
8851 Woonton, W. G., Univ. of Toronto
8852 Luke, G. E., Princeton Univ.
8853 Brooks, C. H., Jr., Univ. of Tex.
8854 Weeg, W. J., Univ. of Tex.
8855 Fernandez, L. A. J., Univ. of Tex.
8856 McComas, W. C., Univ. of Tex.
8857 Harrison, W. H., Univ. of Tex.
8858 Porter, W., Columbia Univ.
8859 Riley, A. J. G., Tufts Coll.
8860 Cree, J. O., Iowa State Coll.
8861 Knutz, J. H., Iowa State Coll.
8862 Longley, K. O., Iowa State Coll.
8863 Evans, S. S., Iowa State Coll.
8864 Merrick, C. I., Iowa State Coll.
8865 Abbott, D. A., Iowa State Coll.
8866 Bartlett, G. S., Iowa State Coll.
8867 Blakeslee, R. O., Iowa State Coll.
8868 Brunner, W. W., Iowa State Coll.
8869 Coquillette, L.W., Iowa State Coll.
8870 Foley, M. J., Iowa State Coll.
8871 Fridholm, B., Iowa State Coll.
8872 Laubenfells, C.R., Iowa State Coll.
8873 Stuart, V. N., Iowa State Coll.
8874 Windenburg, E.L., Iowa State Coll.
8875 Hoeppner, H. L., Tri-State Coll. Engg.
8876 Freehafer, F. K., Univ. of Penna.
8877 Husson, H. L., Univ. of Ill.
8878 Rowe, J. L., Univ. of Ill.
8879 Zen, H., Univ. of Illinois
8880 Koehler, G., Univ. of Illinois
8881 Brooks, F. A., Univ. of Ill.
8882 Reagan, M. E., Univ. of Ill.
8883 Crutcher, W. L., Univ. of Ill.
8884 Wilson, G. C., Univ. of Ill.
8885 McKim, H. A., Jr., Stanford Univ.
8886 Scholz, C. E., Stanford Univ.
8887 Irvine, J., Stanford Univ.
8888 Hammett, H. R., Stanford Univ.
8889 Gray, L. R., Univ. of Ill.
8890 Williams, E. H., Wash. State Coll.
8891 Dequine, G. F., Univ. of Wis.
8892 Johnson, R.J., Tri-State Coll. Engg.
8893 Nash, B. M., Okla. A. & M. Coll.

Digitized by Google

8894 Martin, T. E., Univ. of Texas
8895 Williams, R.C., Penna. State Coll.
8896 Whiteman,R.A.,Penna.State Coll.
8897 Kilpatrick, W. S., Univ. of Mich.
8898 Emmons, F. J., Univ. of Mich.
8899 Knapp, A. R., Colo. Agri. Coll.
8900 Key, G. T., Jr., Ala. Poly. Inst.
8901 Angove, C., Univ. of Wash.
8902 Baechle,C.A.,RensselaerPoly.Inst.
8903 Stone, N.H.,Rensselaer Poly. Inst.
8904 Pippenger, H.F.,Mont. State Coll.
8905 Costa, J. de A., Univ. of Penna.
8906 Eslick, E., Univ. of Tenn.
8907 Etem, C. A., Univ. of Missouri
8908 James, F. E., Poly. Coll. of Engg.
8909 Deering, R. H., Wentworth Inst.
8910 Colburn, W. H., Worcester Poly. Inst.
8911 Scott, J. V., Jr., Drexel Inst.
8912 Gibson, G. W., Drexel Inst.
Total 114

OBITUARY

FERDINAND W. ROEBLING, treasurer and general manager of the John A. Roebling Sons' Company, died at his home, 222 West State Street, Trenton, N.J., March 16, 1917. Mr. Roebling was born in Saxonburg, Penn., Feb. 27, 1842 and was a son of John A. Roebling, the pioneer rope manufacturer in this country.

Mr. Roebling was an officer in many corporations, a member of the Union League Club and Engineers' Club and an Associate of the American Institute of Electrical Engineers.

PERSONAL

MR. JOHN D. BALL has accepted the Professorship of Electrical Engineering at the School of Engineering of Milwaukee, Wisconsin. Mr. Ball is a graduate electrical engineer of Illinois University. During his service for the past ten years in the Testing Department, Standardizing Laboratory and Consulting Engineering Department of the General Electric Company, he has presented to the Engineering Societies and the domestic and foreign technical press a number of articles connected with his investigation of magnetic phenomena.

MR. OWEN E. GRIGSBY who has been electrical engineer and factory manager for the Benjamin Electric Limited of London, England, and who recently returned to the United States has now become Secretary of the Anderson Electric Specialty Company of 562-564 W. Vanburen St., Chicago.

MR. EDWIN G. HATCH, Consulting Engineer, New York City, is arranging for the manufacture in this country of a large quantity of 5 per cent nickel steel turbine blades for Victoria Falls and Transvaal Power Company, Ltd. of South Africa, whose plant serves the Rand Gold Mines. These turbine buckets were previous to the war manufactured in Germany.

MR. W. S. RUGG formerly District Manager of the New York Sales Office of the Westinghouse Electric and Mfg. Company has resigned his position to become Manager of the Railway Department, with headquarters at Pittsburgh.

MR. C. S. COOK has resigned his position of Manager of Railway Department of the Westinghouse Electric and Mfg. Company to become General Manager of the Duquesne Lighting Company of Pittsburgh, Pa.

MR. E. D. KILBURN formerly Manager of the Power and Railway Divisions of the New York office of the Westinghouse Electric and Mfg. Company has been appointed Manager of the New York office.

MR. GEORGE B. TRIPP, formerly Vice President of the United Gas and Electric Engineering Corporation, has been elected President of the Central Construction Corporation of Harrisburg, Penn. and will devote his time in the

Digitized by Google

future to the management of this enterprise.

MR. D. H. BRAYMER, who for the past two years has been engineering editor of the *Electrical World*, has resigned to assume the editorship of the *Electrical Record*. Prior to his connection with the *Electrical World*, Mr. Braymer was editor of *Electrical Engineering* of Atlanta, Ga., and of its predecessor, the *Southern Electrician*. He is a graduate of Cornell University and spent some years with the Electrical Testing Laboratories and the Western Electric Company in New York City before engaging in editorial work.

H. S. FOLEY, who has been connected with the F. S. Pearson companies in Mexico and Barcelona for the past thirteen years, recently resigned and is now connected with the Compagnie Generale d'Electricite, with headquarters in Paris. Mr. Foley is at present in this country arranging for the purchase of machinery and supplies for some of the properties which his company operates in France. Mr. Foley was one of the organizers of the Mexico Section and served variously as Secretary and as Chairman.

ACCESSIONS TO LIBRARY

This list includes books which have been presented to the library of the A. I. E. E. and the U. E. S. during the past month, not including periodicals and other exchanges.

American Telephone and Telegraph Company. Annual Report 1916. New York, 1917. (Gift of Company).

Cancellation and substitution. An address before the Insurance Society of New York, October 5, 1915. (Gift of Insurance Society of New York).

High-Frequency Apparatus. By Thomas S. Curtis. New York, Everyday Mechanics Co., Inc., 1916. (Gift of Author).

New York State Department of Labor. Annual Report of the Industrial Commission, 1915. Albany, 1916. (Gift of State Department of Labor).

New York (State) Public Service Commission, Second District. Annual Report 9th, 1915, volume II. Albany, 1916. (Gift of Commission).

Telephone Apparatus. An introduction to the development and theory. By George D. Shepardson. New York, D. Appleton & Co., 1917. (Gift of publisher).

Underwriters' Laboratories. Electrical Data, February, 1917. Chicago, 1917. (Gift of Underwriters' Laboratories).

Use and Occupancy: Profits and Commissions. Rents and Leasehold Insurance. An address before the Insurance Society of New York, Jan. 30, 1917. (Gift of Insurance Society of New York).

William A. Read, et al. vs. Central Union Telephone Company, et al. Opinion rendered by Judge William E. Dever, January 20, 1917. (Gift of Cassoday Butler Lamb and Foster).

UNITED ENGINEERING SOCIETY

A Brief Description of the Physical and Operating Properties of the Subsidiary and Affiliated Companies of the General Gas and Electric Company, May 1915. New York, n.d. (Gift of Chas. H. Armstrong).

Allentown, Pa. Mayor's Annual Message, 1916.

——Report of Superintendent of the Department of Accounts and Finance of the Public Accounts 1916-1917. (Gift of City Clerk).

American Iron & Steel Institute. Year Book, 1910, 1912-1915. New York, 1910, 1912-15. (Gift of American Iron and Steel Institute).

By-Product coke and gas ovens and systems for the recovery of ammonia, tar and benzols. Designed and built by H. Koppers Company. Pittsburgh, n.d. (Gift of H. W. Nicolson).

Buyers' Guide for Textile Mills. A handy reference book for buyers of textile mill supplies and equipment. New York, n.d. (Gift of Textile World Journal).

Electric Central Station Distribution Systems, their design and construction. Ed. 2. By H. B. Gear and P. F. Williams. New York, D. Van Nostrand Co., 1916. (Gift of Publishers).

Federal Valuation of the Railroads in the United States. Statement prepared by H. C. Phillips, of the developments in connection with Federal valuation as of February 10, 1917. (Gift of Clemens Herschel).

Graphite, 1916. (Gift of Joseph Dixon Crucible Co.)

Motor Cycling Manual. Ed. 3. London, n.d. (Gift of Frank Gilliland).

National Committee for the Prevention of Blindness. Annual Report. 2d, Nov. 1916. New York, 1916. (Gift of L. Cammen).

National Lamp Works of General Electric Company. Abstract—Bulletin of Nela Research Laboratory v. 1, no. 2. Cleveland, 1917. (Gift of National Lamp Works).

New York (City) Department of Water Supply, Gas and Electricity. Communication from Commissioner William Williams to the Board of Estimate and Apportionment, transmitting report of Deputy Commissioner Wilcox upon the Citizens Water Supply Com-

Digitized by Google

pany of Newton, Borough of Queens. Feb. 5, 1917.

——Report of Delos F. Wilcox, in relation to the Citizens Water Supply Company of Newton, Oct. 7, 1916. (Gift of City of New York Department of Water Supply, Gas and Electricity).

Physical Experiments for Engineering Students. By Samuel Sheldon and Erich Hausmann. Part I. Mechanics, Sound, Heat and Light. New York, D. Van Nostrand, Co., 1917. (Gift of Publishers).

Russia. Scientific Committee of the Ministry of Agriculture. Bulletin of Bureau of Agricultural Mechanics. Vol. 8, nos. 1-3. n.p. 1916. (Gift of Committee).

Russian Electrotechnical Commission. Standardization Rules of the American Institute of Electrical Engineers. (In Russian) n.p. 1916. (Gift of Commission).

Russian Electrotechnical Terminology. By L. D. Tsaxoff. (Russia) n.p. 1916. (Gift of International Electrotechnical Commission).

Seaboard Air Line Railway Company. Annual Statement 1909-1916. Portsmouth, Va. 1909-16. (Gift of Company).

Springfield (Ill.) Insurance Department. Addresses and Papers on Insurance. By R. M. Potts. Springfield, 1917. (Gift of Insurance Department).

Strength of Ships. By A. J. Murray. New York. Longmans, Green & Co., 1916. (Gift of Publisher).

Tentative Valuation by Interstate Commerce Commission, Feb. 14, 1917. Elgin, Joliet & Eastern Railway. (Gift of Clemens Herschel).

The Development of the Steam Engine. By Max Toltz. (Gift of W. P. Cutter).

The Toltz-Lipschutz Acetylene Car Lighting System. By Max Toltz. (Gift of W. P. Cutter).

U. S. Bureau of Standards. Circular nos. 14, ed. 5; 16, ed. 4; 30, 35, ed. 2; 38, 3d. 2; 48-49, ed. 2; 51; 52, ed. 2; 53, 54, ed. 2; 55, 57, ed. 2; 59, 60.

——Scientific Papers. nos. 267-8, 271-6, 278-9; 282-91, 293-5.

——Technologic papers. nos. 25, 41, 70, 73, 76, 77, 79, 82.

U. S. Bureau of Standards. Weights and Measures. 11th Annual Conference. Washington, 1917. (Gift of Bureau of Standards).

U. S. Interstate Commerce Commission. Valuation in the matter of the property of the Atlanta, Birmingham & Atlantic Railroad Company, Georgia Terminal Company and Alabama Terminal Railroad Company. Hearing, Washington, Jan. 29-Feb. 3, 1917. (Gift of Clemens Herschel).

Western Reserve University. Catalogue, 1916-17. Cleveland, 1917. (Gift of University).

Who's Who in America. 1903-05. Chicago, 1905. (Gift of Clemens Herschel).

EMPLOYMENT BULLETIN

Vacancies.—The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN. The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-188. Wanted: Electrical Engineer with practical experience in the design, manufacture and application of direct-current motors and controllers for hoisting service, electric cranes, etc. Must have good training, technical education, and ability to work into responsible position. Reply should give full particulars of previous employment, experience, salary expected, etc.

V-218. Experienced meter tester who is capable of testing all types of recording and indicating meters, repairs, etc., both in central station and laboratory. Must understand high-tension work and be able to test switchboard meters when in service. Excellent opportunity for right man, with chances for advancement and good salary. New England location. State age, experience, references and salary to start.

V-219. Production Manager. A concern manufacturing metal products, in the vicinity of New York, has an

Digitized by Google

opening with a good future for a production manager. Must have had practical experience in every branch, such as shop work, drawing room work, tool designing, etc.; must also have had successful experience of at least five years; must be thoroughly informed in modern cost and planning department methods, electrical manufacturing experience preferred, although not absolutely essential. Salary to start about $3,500.

V-220. An engineer who has had experience in designing modern direct-current motors in medium sizes for quantity manufacture. Must have done original work and be able to produce designs that will result in competitive machines as to performance and cost. Technical education a requisite.

V-221. Transformer Draftsman-Designer. One with experience in low voltage, high current transformers as used in induction furnace or welding work. An unusual opportunity to connect with a progressive, rapidly growing concern; location near Boston. Please state fully experience and salary desired in first letter, to receive attention.

V-222. Electrical Draftsman for generating and substation design, on large capacity, high and moderate voltage systems. Applicants must state nationality, education, experience, age, whether married or single, and salary desired. Location, Canada.

V-225. Engineer. Young technical graduate to engineer design and production of electro-mechanical devices, and to conduct performance tests on standard and special designs. Salary to start $100. Location, Middle West.

V-226. Technical graduate in electrical engineering for laboratory work. Must be able to adapt himself to the various personnel of large organization. Must also have a personality which will enable him to meet customers, adjust complaints and develop into sales engineer. Man with about a year's experience in operation of motors and generators preferred. Give full particulars. Good opportunity.

V-227. Assistant to Manager. A concern manufacturing electrical specialties, located near New York, requires an assistant to its factory manager. Must have had some shop experience and able to follow up work in factory and see that directions are properly carried out. Technical education desirable but not essential. Salary to start about $30.

V-228. Electrical Draftsmen. Several openings for electrical draftsmen with switchboard experience in specialty company located near New York. State salary desired.

V-229. Opportunity for an electrical engineer of broad experience in the development and manufacture of electrical apparatus, particularly transformer coils for X-ray outfits. He should be capable of managing the engineering department of a progressive industrial plant and should possess a thorough knowledge of mechanics as well as experience in the electrical field. Applicants should give full particulars with references, experience, etc. Answers will be treated with strict confidence. Location, New York.

V-230. An engineering corporation has several vacancies for young men with some technical training for valuation and inventory work. Moderate salary to start with reasonable chance for advancement.

V-231. Wanted: Plant Engineer with a knowledge of general factory planning, arrangement of machine tools, motor applications, piping and power house work. Please give full particulars.

V-232. Wanted: Electrical Draftsman—Must be experienced in laying out electric generating stations and high-tension substations. State age, experience and salary expected. Address P. O. Box 1902, Philadelphia, Pa.

The U. S. Civil Service Commission announces an open competitive examination for electrical draftsmen, especially those with marine electrical experience. Salary range from $3.52 to $6.00 per diem. Applications will be received at any time and papers rated immediately. Those desiring this examination should apply at once for Circular No. 1697 describing the requirements, and Form 1312, to the U. S. Civil Service Commission, Washington, D. C.

The Navy Department announces an examination to fill vacancies in the grade of Assistant Civil Engineer, Corps of Civil Engineers, U. S. Navy. To be eligible a candidate must be not more than 26, an American citizen, possess a degree showing that he has completed a course in engineering; must have had eighteen months' experience since graduation. Appointees are commissioned in the grade of Assistant Civil Engineer, Corps of Civil Engineers of the Navy, with the rank of lieutenant. Pay about

Digitized by Google

$2,500. The highest rank in the Corps of Civil Engineers is rear admiral, with pay of about $9,500. For full information address the Chief of Bureau of Yards and Docks, Navy Dept., Washington, D. C.

MEN AVAILABLE

699. Electrical Engineer, at present employed, desires change. Sixteen years' experience—wiring, overhead and underground transmission and maintenance, and shop repair work. Also experienced in operation of boilers, turbines, engines and mechanical refrigeration.

700. Engineer, (30), graduate, all-round experience; offers services. Expert in lecturing, writing, editing and making up technical publicity matter, advertising copy and correspondence. Specialist in the development of new business fields by the above methods. Salary $2500 minimum.

701. Graduate in electrical engineering, correspondence school course. Eight years in charge electrical construction for engineering firm; two years operating in substation; two years' power plant operation. Desires position where past experience may be of service.

702. Erecting Engineer open for engagement supervising plant construction or marine installations—hydraulic equipment, electrical equipment, Diesel and semi-Diesel engines. Technically trained, thoroughly experienced, steady, energetic, capable. Now on West coast but will go anywhere in U. S. or Canada.

703. Electrical Engineer, technical education, thorough training, theoretical and practical, in operation and design of electrical power installations, high-tension lines and power sales experience. At present superintendent and chief engineer for large power company in the west. Can accept position of responsibility on short notice. Mem. A. I. E. E.

704. Executive Engineer, technical graduate, (1907). Thirteen years' training with sufficient time devoted to each of the following fields—executive, engineering, sales, accounting, operating, construction, system, valuations and reports—electrical and mechanical, public service and industrials. This training for sale in connection with brains, energy and aggressiveness.

705. Construction or Maintenance Engineer with technical education and a varied experience in central and substation construction and maintenance. At present with Commonwealth Edison Co., Chicago. Formerly with Allis-Chalmers Mfg. Co. Good character; temperate; economical. Available at short notice. Desirous of position requiring initiative and executive ability. Salary $1800.

706. Superintendent. Has had long practical experience in all branches of central station work. Past five years superintendent of a progressive company gaining 10,000 customers in 1916. Out on account of change in management. Desires similar work with moderate size company or head of technical department of large company.

707. Graduate Electrical Engineer, age 36, four years' testing and executive experience with G. E., ten years teaching electrical engineering and physics. Ready for anything offering opportunities for growth and advancement. Will consider propositions for work in educational or engineering lines. Minimum salary considered $2,000.

708. Technical Graduate, with four years' practical experience in construction, maintenance, repair and operation of power plants and high-tension apparatus, desires position where ability is recognized and rewarded, preferably with engineering corporation. Willing to go anywhere if opportunity is satisfactory. Age 30; single, strictly temperate. Available immediately.

709. Graduate Electrical Engineer, 24, married, desires position in sales office or as assistant engineer in an industrial organization. Two years with G. E. Co., on tests and engineering office and nine months with large automobile company in engineering office.

710. Engineer-Manager, with 17 years' utility experience, desires position where intelligence, energy, capacity and business sense, added to amiable but firm disposition with technical training can be appreciated. Experience includes operation, erection, construction, superintendence and commercial management, executive work on modern electrical power systems. Commercial engineering with progressive engineering, utility or industrial concern desired.

711. Electrical and Mechanical Engineer, 39, technical graduate; practical shop experience, including inspection of machinery under manufacture throughout U. S.; sixteen years' executive, engineering experience with large projects—constructing and operating power plants, transmission systems and irrigation works; desires engagement

Digitized by Google

with power company, consulting engineers, or industrial plant, Southwest preferred.

712. Electrical Engineer, technical graduate, Mem. A. I. E. E., Assoc. Mem. A. S. C. E., eighteen years' practise, six years chief engineer and technical expert for a state public service commission on valuation, service regulation and rate work. Wishes responsible position with large electric company. Can leave on one month's notice.

713. A-C. Motor Expert, now employed, and successful, wishes opportunity requiring executive ability, personality and understanding of men, as well as unusual technical ability. Teaching experience and five years with large manufacturer. Age 28. Minimum salary $1800.

714. Technical man of research and teaching experience, desires position, in consulting engineering or in research work. Six years' experience since graduation; two in central station work, four in responsible teaching and research work at first-class university. Will not change unless good prospect for advancement. Salary $1800.

715. Professor of electrical engineering and physics, Mem. A. I. E. E., desires to change. Four years practical and one year research engineering. Five years very successful teaching experience. Thoroughly conversant with practical engineering and advanced theory of electrical engineering and physics. Available also for summer work in education or engineering.

716. Graduate Electrical Engineer, two years' experience in factory and general testing, would like to affiliate with a company having use for a sales engineer.

717. Engineer. Domestic and foreign experience in street railway and lighting work. Age 36. Investigations and reports. Thoroughly versed in business and legal affairs. Speaks Portuguese and Spanish fluently. Mem. A. I. E. E. and Assoc. M. A. S. C. E.

718. Electrical Engineer, graduate of Minnesota and now completing post-graduate Stanford. Available any position June 1. Six years' experience in factory, plant test, line work, drafting, inventories, operating, meters and complaints, records, local agent, suburban distribution, and transmission. Never sick nor injured; not afraid of work. Pacific Coast preferred.

719. Technical Graduate, with thirteen years' practical experience in design, construction and operation of power plants, substations and transmission lines. Perfectly familiar with high-tension transmission, also Diesel oil engines and operation of same. Position in the South or Southwest preferred.

720. Electrical Engineer, age 27, four years' engineering development and manufacturing experience with large corporation. Wants position as manager's assistant in small electrical manufactory. Ability to handle men and get results. Exceptional knowledge of good English. Requires place where promotion and remuneration come by efficacy, not by schedule.

721. Advertising Manager or Assistant. Graduate electrical engineer, 28, now assistant business manager of leading technical journal, seeks new connection where initiative and proven ability will insure real opportunity. Prefer concern manufacturing electrical equipment or for power plant field. Independently acting as advertising manager for concern manufacturing highly technical product.

722. Telephone Engineer, age 42, married, desires position as engineer, superintendent or manager of a telephone plant or system. Eighteen years' experience, mostly with large companies. Practical construction and maintenance experience. Can make up estimates and appraisals. Technical education with some sales experience. At liberty about May 1.

723. Graduate Electrical Engineer, age 25, having had General Electric test, also experience in designing and estimating on control apparatus, desires position along commercial lines requiring executive ability. At present employed, but desires position with greater opportunities for advancement.

724. Electrical Engineer, M. I. T. graduate, available for position with consulting engineer or contractor engaged in industrial power plant and equipment work. Seven years' experience in mechanical-electrical engineering including design, construction, operation and maintenance of isolated industrial power plant, safety engineering and transportation economy.

725. Sales Engineer now employed as construction superintendent by largest Eastern engineering corporation, desires to return to sales work. Has managed sales office in western territory. Salary and location secondary to agreeable working conditions.

Digitized by Google

726. Cost Accountant and Auditor, with experience also as Secretary and Treasurer, desires to change. Employed at present installing cost system in manufacturing plant. Thoroughly familiar with corporation accounts.

727. Electrical and Mechanical Engineer with broad experience in office and field relative to electrical machinery and apparatus, power stations, steam and gas engines, structural steel, concrete and hydroelectric work, research; versed also in engineering theories and mathematics sufficiently to walk the untrodden road to success; is open for engagement.

728. Sales Engineer, desires to connect preferably with electric machine manufacturer. Expert on motor application. Present position unsatisfactory.

729. Position as instructor in electrical engineering desired by married graduate, B. S. and E. E. degrees. Experience—four years wiring and construction; two and a half years power switchboard operation; two years in engineering department of central station.

730. Electrical Graduate, age 30, with testing experience, now employed in engineering department of electrical manufacturing company, desires responsible position with consulting engineering firm or electrically equipped manufacturing company. Six years' broad experience in design, application, and testing of induction motors, a-c. commutator motors, and Scherbius speed regulating sets. Interview desired.

731. Assoc. A. I. E. E., with technical education, receiving degree in June, 1917; machine shop and automobile experience; desires position in power plant economy, testing department, or similar line in or near New York City. Hard worker, willing and adaptable. Age 22.

732. Executive Engineer desires position with industrial or public utility company. Graduate electrical engineer; age 37. Broad executive and engineering experience, including eleven years with large railway system; also power transmission, public utility, appraisals, industrial development, etc. Interview requested.

733. Engineer-Executive, Fel. A. I. E. E. Broad experience in managing public utilities, light, power, gas, interurban railways; experienced in construction and operation of steam turbine and hydroelectric plants, high-tension transmission lines. Particularly good in light and power and railway business, strong on advertising, publicity and public policy. Open for engagement.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917) **SECRETARY.**
GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY.
RALPH W. POPE

LIBRARIAN.
W. P. CUTTER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
†LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to April 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.
N. A. Carle, George A. Hamilton,
John H. Finney, William McClellan,
Bancroft Gherardi, J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.
N. A. Carle, Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.
Frederick Bedell, F. W. Peek, Jr.
Philander Betts, F. L. Rhodes,
H. H. Clark, D. W. Roper,
J. G. De Remer, Harris J. Ryan,
H. A. Hornor, T. H. Schoepf
Edward P. Hyde, Charles P. Steinmetz,
L. E. Imlay, N. W. Storer,
E. H. Martindale, Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
Frederick Bedell, L. T. Robinson,
M. G. Lloyd, C. E. Skinner.

CODE COMMITTEE.

Parley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 W. 23rd Street, New York.
E. B. Katte, W. I. Slichter,
F. L. Rhodes, Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
J. G. De Remer, A. M. Schoen,
Paul M. Lincoln, J. H. Tracy,
and the chairmen of all Institute Sections, *ex-officio*.

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.
G. M. Baker, W. G. Chace,
S. H. Blake, H. W. Flashman,
E. H. Martindale.
and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
E. A. Carolan, A. M. Hunt,
John J. Carty, William McClellan,
Fredk. Darlington, H. H. Porter,
Gano Dunn, C. S. Ruffner,
John B. Fisken, A. M. Schoen,
L. B. Stillwell,

COMMITTEE ON DEVELOPMENT OF WATER POWER

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.
F. O. Blackwell, Nicholas S. Hill, Jr.,
Francis Blossom, E. A. Lof,
Gano Dunn, W. V. N. Powelson,
L. B. Stillwell.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, H. M. Hobart,
Frederick Bedell, H. D. James,
Joseph Bijur, P. Junkersfeld,
L. F. Blume, A. E. Kennelly,
James Burke, G. L. Knight,
G. A. Burnham, A. S. McAllister,
N. A. Carle, W. M. McConahey,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
W. A. Del Mar, C. E. Skinner,
E. J. Edwards, A. J. Slade,
H. W. Fisher, N. W. Storer,
R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, M. I. Pupin,
B. A. Behrend, E. B. Rosa,
Louis Bell, Charles F. Scott,
James Burke, Clayton H. Sharp,
John J. Carty, Samuel Sheldon,
Gano Dunn, C. E. Skinner,
H. M. Hobart, Charles P. Steinmetz,
John W. Lieb, Elihu Thomson,
R. B. Owens, Philip Torchio.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, Charles A. Terry,
John F. Kelly, B. F. Wood,

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.
A. E. Kennelly, Chairman, Robert T. Lozier,
S. G. McMeen.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.
Charles F. Brush, N. W. Storer,
C. C. Chesney.

Term expires July 31, 1920.
Carl Hering, Harris J. Ryan.

Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.
B. A. Behrend, Paul M. Lincoln,
William McClellan.

Term expires July 31, 1918.
C. A. Adams, Harold Pender,
C. E. Skinner.

Ex-Officio.

H. W. Buck, President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to April 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
100 Broadway, New York.

J. M. Drabelle,
C. C. Egbert,
W. S. Gorsuch,
John Harisberger,
A. H. Kruesi,
Paul M. Lincoln,
Wynn Meredith,
I. E. Moultrop,
S. A. Moss,
R. J. S. Pigott,
Cecil Poole,
E. F. Scattergood,
F. A. Scheffler,
W. R. Thompson,
Philip Torchio,
H. L. Wallau,
B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,
M. T. Crawford,
E. E. F. Creighton,
H. H. Dewey,
P. M. Downing,
H. W. Fisher,
F. A. Gaby,
W. T. Goddard,
O. A. Havill,
R. F. Hayward,
J. P. Jollyman,
P. M. Lincoln,
W. E. Mitchell,
G. J. Newton,
L. C. Nicholson,
W. D. Peaslee,
Stefaan Piek,
C. S. Ruffner,
H. J. Ryan,
F. D. Sampson,
H. E. Shedd,
Julian C. Smith,
P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman.
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,
A. H. Babcock,
Reinier Beeuwkes,
E. J. Blair,
L. P. Crecelius,
J. V. B. Duer,
George Gibbs,
W. J. Harvie,
Hugh Hazelton,
E. B. Katte,
P. J. Kearny,
William McClellan,
John Murphy,
W. B. Potter,
E. D. Priest,
Charles H. Quinn,
Clarence Renshaw,
A. S. Richey,
Charles F. Scott,
John B. Taylor,
H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,
J. H. Davis,
James Dixon,
A. M. Dudley,
Herbert D. Dwight,
F. W. Ells,
J. E. Fries,
F. R. Fishback,
R. H. Goodwillie,
A. L. Hadley,
G. A. Johnstone,
C. A. Kelsey,
C. L. Kennedy,
Charles D. Knight,
A. H. Lawton,
A. M. MacCutcheon,
A. G. Pierce,
James M. Smith,
H. Weichsel,
J. B. Wiard,
R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,
C. E. Clewell,
J. R. Cravath,
T. S. Perkins,
Richard C. Powell,
E. B. Rosa,
W. D'A. Ryan,
Clayton H. Sharp,
W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,
W. H. Blood, Jr.
Fred A. Bryan,
C. L. Cory,
Harry Clifford Eddy,
W. B. Jackson,
A. H. Kruesi,
William McClellan,
Norman C. McPherson,
Allard Smith,
W. G. Vincent,
George W. Wittemore,
Clifton. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
72 W. Adams St., Chicago, Ill .

L. L. Elden,
G. Faccioli,
V. E. Goodwin,
E. M. Hewlett,
Paul M. Lincoln,
A. A. Meyer,
L. C. Nicholson,
N. L. Pollard,
S. D. Sprong,
Philip Torchio,
H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,
F. A. J. Fitzgerald,
A. F. Ganz,
F. A. Lidbury,
F. G. Liljenroth,
Eugene F. Roeber,
J. A. Seede,
R. Tschentscher.

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,
A. C. Crehore,
G. Faccioli,
C. L. Fortescue,
W. S. Franklin,
A. E. Kennelly,
E. B. Rosa,
Harris J. Ryan,
Clayton H. Sharp,
C. P. Steinmetz,
P. H. Thomas,
J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
195 Broadway, New York.

E. F. W. Alexanderson,
R. E. Chetwood,
M. M. Davis,
C. L. Fortescue,
H. M. Friendly,
F. B. Jewett,
S. M. Kintner,
Wm. Maver, Jr.,
Kempster B. Miller,
H. Mouradian,
W. O. Pennell,
Allard Smith,
John S. Stone,
John B. Taylor,
J. L. Wayne, 3rd.
G. M. Yorke,

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.

D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,
M. W. Day,
G. E. Edgar,
W. L. R. Emmet,
W. R. Furlong,
H. L. Hibbard,
Guy Hill,
O. P. Loomis,
G. A. Pierce, Jr.,
H. M. Southgate,
E. A. Sperry,
Wilfred Sykes,
F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,
Frank H. Armstrong,
Graham Bright,
W. A. Chandler,
F. J. Duffy,
L. C. Ilsley,
R. L. Kingsland,
Charles Legrand,
Charles M. Means,
K. A. Pauly,
H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,
F. B. Crosby,
E. Friedlaender,
E. S. Jeffries,
D. M. Petty,
A. G. Pierce,
J. C. Reed,
R. Tschentscher,
Brent Wiley,
R. B. Williamson
J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.

Alexander Gray,
E. J. Henkhe,
E. A. Loew,
William McClellan,
Chester W. Rice,
C. E. Skinner
R. D. Thomson,

Digitized by Google

SPECIAL COMMITTEES.

Revised to April 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
F. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman,
Massachusetts Institute of Technology, Boston, Mass.
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. F. Scott.

COMMITTEE ON NATIONAL DEFENSE

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.

F. C. Bates, Secretary,
30 Church Street, New York,

B. J. Arnold, D. C. Jackson,
A. H. Babcock, John W. Lieb,
Philander Betts, P. M. Lincoln,
H. W. Buck, Ralph D. Mershon,
J. H. Cuntz, A. M. Schoen,
J. J. Carty J. Franklin Stevens.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S. McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

Ralph D. Mershon, Paul M. Lincoln,
C. O. Mailloux, John J. Carty.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Harold Pender, Edward D. Adams,
W. I. Slichter, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan,
John J. Carty.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Parley Osgood, F. B. H. Paine,
Percy H. Thomas.

ON JOINT NATIONAL COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly,

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.

Robert Julian Scott, Christchurch, New Zealand.

T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.

W. G. T. Goodman, Adelaide, South Australia.

James S. Fitzmaurice, Perth, West Australia.

L. A. Herdt, McGill Univ., Montreal, Que.

Henry Graftio, Petrograd, Russia.

Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.

A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France.

Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.

John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to April 1, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg.Atlanta,Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St., Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, 433 West Forest Ave., Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Union Tel. Co. Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	Gordon Campbell	M. B. Carroll, G. E. Co., West Lynn, Mass
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7. '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, 1220 Spalding Bldg., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	Lucien Buck, 1416 Lake Avenue, Rochester N. Y.
St. Louis.....Jan. 14, '03	A.McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	E. T. J. Brandon	Wills Maclachlan, 910 Excelsior Life Building, Toronto, Ont.
Urbana.....Nov. 25, '02	I. W. Fisk	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University....May 17, '10	N. J. Rehman	E. C. Hageman, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Marc Holzer	A. C. Maynard, University of California, Berkeley, Cal.
Carnegie Inst. of Tech..May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col..Jan. 10, '08	R. H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	N. M. Foster	G. M. Bowman, 1517 New Hampshire, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Samuel McC.Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute,Chicago.
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of...May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr., and Mech. Arts.Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of.Feb 15, '17		
Norwich University....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University..Dec. 20, '02	H. D. Bender	L. W. Birch, 138 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of....Oct. 11, '12	H. M. Richards	R. E. Heffner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly,	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst..Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of...Dec. 13, '07	D. M. Alexander	C. W. Cutler, 702 California St., Pullman, Wash.
Washington Univ.....Feb. 6, '04	Charles A. Lieber	R. W. MacDonald, Washington University, St. Louis, Mo.
Washington, Univ. of..Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst...Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 58

Digitized by Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI MAY, 1917 Number 5

ANNUAL BUSINESS MEETING AND EDISON MEDAL PRESENTATION

The Annual Business Meeting of the A. I. E. E. will be held in the auditorium of the Engineering Societies Building on Friday, May 18, at 8:15 p. m. The Board of Directors will present its report for the fiscal year ending April 30, 1917, which will include a detailed statement of the financial status of the Institute and a summary of the work accomplished by the standing and special committees during the year. The Committee of Tellers will present its report on the election of officers for the coming administrative year. The ceremony of presentation of the Edison Medal will follow immediately after the business meeting.

PRÉSENTATION OF EDISON MEDAL

The seventh Edison Medal which was awarded to Mr. Nicola Tesla on December 13, 1916, "for meritorious achievements in his early original work in polyphase and high-frequency electric currents" will be presented to Mr. Tesla at the annual meeting. President H. W. Buck will preside and the program will be as follows:

Address by Dr. A. E. Kennelly, Chairman, Edison Medal Committee, outlining the origin and purpose of the Edison Medal.

Address by Charles A. Terry, giving historical facts in regard to Tesla's patents, contributions to the arts, etc.

Address by B. A. Behrend.

Presentation of the Edison Medal to Nikola Tesla by President Buck.

Response by Mr. Tesla.

Ladies are cordially invited to attend this meeting.

A. I. E. E. ANNUAL CONVENTION, JUNE 26-29

The Annual Convention of the Institute as previously announced will be held at Hot Springs, Va., June 26 to 29, 1917. The Homestead Hotel will be the convention headquarters. The following convention committee has been appointed by President Buck to make necessary arrangements for the convention with the exception of the technical sessions which are arranged by the Meetings and Papers Committee.

J. Franklin Stevens, Chairman, Philadelphia, Pa.
N. A. Carle, Newark, N. J.
Harold Goodwin, Jr., Philadelphia, Pa.
Walter A. Hall, Lynn, Mass.
P. Junkersfeld, Chicago, Ill.
Charles Robbins, Pittsburgh, Pa.
L. T. Robinson, Schenectady, N. Y.
J. B. Whitehead, Baltimore, Md.

The tentative list of convention papers for the first four sessions as published in the April PROCEEDINGS has been confirmed. The paper for the fifth session will be *Economical Combination of Water Power and Steam Plant and a Simple Method of Solution*, by H. S. Putnam. In addition to this, a paper on *Cooling of Oil Immersed Transfor-*

Digitized by Google

mer Windings After Shutdown by V. M. Montsinger, which was scheduled for the Schenectady meeting which was subsequently canceled, will be presented and discussed at this session.

AMENDMENT TO BY-LAWS

At the meeting of the Board of Directors held April 13, the following by-law, which had been recommended by the Meetings and Papers Committee, was adopted:

Each technical committee shall, at the annual convention, present a report covering the work of the year and giving plans and suggestions for future activities. These reports shall be, whenever practicable, published with discussion.

It is the intention of the chairmen of the various technical committees, all of whom are ex-officio members of the Meetings and Papers Committee, to inaugurate the practise of presenting an annual report, at the Annual Convention of the Institute to be held at Hot Springs, Va., June 26-29, 1917.

THE ENGINEERING SOCIETIES IN NATIONAL DEFENSE

By Gano Dunn, Chairman
Engineering Committee, National Research Council.

The engineering profession which has been so prompt to volunteer its professional and military services to the Government in support of National Defense is now in contact with the various Government agencies, as follows:

First, through the Naval Consulting Board and its formerly existing Committee on Industrial Preparedness, with the origin and organization of which Board the engineering profession is already familiar. Each of the National Engineering Societies and certain other Societies by contributing two members to the Naval Consulting Board has afforded the Navy and War Departments and the Council of National Defense a highly expert Board for passing upon inventions and developing them in the new Government Laboratory that has been organized.

Second, in a more or less informal way, through the joint Committee on Engineer's Reserve Corps and the Military Engineering Committee of New York, the military services of engineers are being organized and offered to the Government, and an Engineer's Regiment is recruiting in New York.

The Constitutions of some of the National Engineering Societies were found to contain such limitations that these Societies could not take formal action in military matters. A little over a year ago the Military Engineering Committee organized itself through the spontaneous action of a group of leading engineers, including a number of Presidents, Past Presidents and other prominent officers of the National Engineering Societies to an extent that gave the Committee a character representative of those Societies although this character has only recently been confirmed by the action of the Societies themselves.

Third, through the National Research Council created at the request of President Wilson by the National Academy of Sciences, "to bring into cooperation existing Governmental, educational, industrial and other scientific and research organizations with the purpose of encouraging investigations of natural phenomena, the increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the National Defense, and such other applications of science as will promote the National security and welfare."

The work of the National Research Council, the offices of which adjoin the offices of the Council of National Defense, is carried on through the agency of central committees covering each of the physical sciences and chemistry, mathematics, medicine, hygiene, agriculture and other subjects, including a Committee on Engineering.

To this Committee on Engineering

Digitized by Google

each of the National Engineering Societies has contributed two representatives and stands ready to contribute others as called for. With the engineers who are members of the National Research Council, these constitute the Engineering Committee.

The representatives so far named from the American Society of Civil Engineers are George F. Swain, Edgar C. Marburg and Clemens Herschel; from the American Institute of Mining Engineers, Pope Yeatman, Albert Sauveur, Charles F. Rand and George K. Burgess; from the American Society of Mechanical Engineers, W. F. M. Goss, John R. Freeman, C. D. Young, Wm. F. Durand, John A. Brashear, Hollis Godfrey, Howard E. Coffin and Ambrose Swasey; from the American Institute of Electrical Engineers, Frank B. Jewett, Clayton H. Sharp, Gano Dunn, C. E. Skinner, Michael I. Pupin, S. W. Stratton, Elihu Thomson and John J. Carty; from the American Institute of Consulting Engineers, Lewis B. Stillwell.

This Engineering Committee under formal request of the Council of National Defense in a resolution dated February 28th, 1917, addressed to the National Research Council brings to the aid of the National Defense Council directly through its Director, the professional services of engineers in the realm of engineering research, and it constitutes the connection between the Council of National Defense and the various National Engineering Societies through which services offered by those Societies to the President of the United States may be called upon in the solution of problems in scientific and engineering research.

In addition to supporting the Government in Engineering Research this Committee also brings to the aid of the Government through the National Research Council such general engineering services as are auxiliary to research where these services are needed by any of the other Committees of the Council as incidental to research problems on which they are at work.

The National Engineering Societies have a further relation to the National Research Council through the Engineering Foundation which these Societies established to administer the munificent gift of Ambrose Swasey for the fostering of research in science and engineering. Through the action of the engineers the whole available income from this gift is now devoted to the organization and operation expenses but not the research expenses of the Council.

As has been stated, the contact of the engineering profession with National Defense through the Engineering Committee of the National Research Council covers only those services involved in science and engineering research with the addition of such general engineering services as are auxiliary.

Other, or general services in the engineering field are articulated with the National Defense as follows:

Fourth, through an Engineering Section of that Committee of the Advisory Commission of the Council of National Defense which is under the direction of Dr. Hollis Godfrey, to whom the Defense Council has assigned supervision of general engineering matters, including education.

Dr. Godfrey is now in course of completing the formation of this Committee by calling upon each National Engineering Society and certain other Engineering Societies to contribute two representatives whom he may appoint members of the Engineering Section of his Committee, so that services needed by the Council of National Defense in the realm of general engineering may be placed at its disposal, either by the individual members of the Committee or through them by other members of the Engineering Societies upon whom the Council of National Defense may call.

The above four channels indicate the broad extent to which the members of the engineering profession, in patriotic response to the Country's need, have come forward to render services.

Digitized by Google

MEMORIAL TO THE LATE PROF. SILVANUS P. THOMPSON D. Sc., F. R. S.

To the Membership of the American Institute of Electrical Engineers:

A fund is being raised to purchase the very valuable Scientific Library of the late Dr. Thompson, and to present it to the Institution of Electrical Engineers, as a Memorial of his life and work, the Library to be accessible to the public on the same conditions as the Ronalds Library of the Institution of Electrical Engineers in London. A committee of fifteen prominent scientists and engineers, has been appointed in England, with Mr. W. M. Mordey acting as chairman, to carry out the plan, and to raise funds for the purchase of the library, the price of which is $20,000 (£4000).

An invitation to contribute to the purchasing fund has already been issued to the membership of the Institution of Electrical Engineers in Great Britain.

The Thompson memorial library is to be presented to the Institution of Electrical Engineers, as a permanent adjunct to the electrical library of that Institution.

In response to a suggestion received from the committee in charge of the plan, and with the approval of the President and Board of Directors of the American Institute of Electrical Engineers, the above facts are hereby presented to the A. I. E. E. members, so that they may have an opportunity of contributing to the purchase fund.

The late Professor Thompson had so many friends, students and admirers in America, and was known to so many electrical engineers by his extensive and classical publications on electrical science and engineering, that the committee in England felt it would be only a matter of courtesy and sympathy to open the subscription list to the American Institute.

Dr. Thompson was an Honorary Member of the A. I. E. E. He was also one of the British Delegates to the International Electrical Congress of Chicago in 1893.

Subscriptions to the Thompson memorial library fund may be addressed to F. L. Hutchinson, Secretary, American Institute of Electrical Engineers, 33 West 39th Street, New York City, who has kindly undertaken to receive and collect the same, and to forward them, with the list of contributors, to the British committee.

ELIHU THOMSON,
A. E. KENNELLY.

GREETINGS FROM FRENCH ENGINEERS

Immediately after the declaration of war by the United States Congress, the following cablegram from the Société Internationale des Electriciens, Paris, France, was received by the American Institute of Electrical Engineers:

"La Société Internationale des Electriciens reunie ce jour à Paris en sèance mensuelle adresse a l'American Institute of Electrical Engineers ses acclamations unanimes pour l'acte historique par lequel le Président et le Parlement des Etats-Unis interprêtes du peuple Americain décident de prendre les armes pour sauvegarder les droits de l'humanité civilisée et en assurer le prochain triomphe."

(TRANSLATION)

The International Society of Electricians, at its monthly meeting held to-day in Paris, sends to the American Institute of Electrical Engineers its unanimous applause for the historic act by which the President and the Congress of the United States, interpreters of the American people decided to take up arms to safeguard the rights of civilized humanity and insure its coming triumph.

President H. W. Buck, on behalf of the Board of Directors cabled in reply as follows:

"The American Institute of Electrical Engineers, through its Board of Directors in session, desires to express its sincere appreciation of your message of good will. We hope that our co-operation with you in this great cause will still further strengthen the bonds of sympathy which we have always held with the electrical engineers of France."

Digitized by Google

THE PROBLEM OF SELECTING PAPERS

BY L. T. ROBINSON, chairman,
Meetings and Papers Committee.

In accepting papers for publication and arranging for their presentation at the various meetings of the Institute, the Meetings and Papers Committee has tried to keep constantly before it the wide scope and great variety of what may today reasonably be classed as electrical engineering. The Secretary has recently received and submitted to the Committee two letters. One member writes:

> I am particularly interested in the research work being done in electrochemistry and physics ..... It does seem to me that we might have a few papers on subjects dealing with research work.

Another member writes:

> The Institute publications are full of long, tedious, mathematical calculations describing details of electrical machinery design or of transmission line design or of many similar lines but practically none of these papers has the material presented in the form that can be used by the busy practical engineer who is engaged in that particular line and it is of absolutely no value to the engineer doing general consulting work.

Still another member takes exception to the attitude of the Committee which he feels is against publication and presentation of papers involving higher mathematics and that the prestige of electrical engineering in America is thereby lowered.

These three view points are somewhat difficult to reconcile. The Committee is governed in its selections of papers by Article I, Section II, of the Constitution which reads as follows:

> Its object shall be the advancement of the theory and practise of electrical engineering and of the allied arts and sciences, and the maintenance of a high professional standing among its members. Among the means to this end shall be the holding of meetings for the reading and discussion of professional papers and the publication of such papers, discussions and communications as may seem expedient.

The Committee feels that it is not always possible to meet the requirements of any special branch of electrical engineering with enough completeness to supply all the needs of the workers in that particular line. On the other hand the intention has always been not to confine the publications to one branch of the work nor to exclude papers in which the authors found it necessary to employ a highly mathematical form of presentation.

The Committee has never rejected a paper merely because it involved higher mathematics. On the other hand, it has rejected a number of papers which were purely mathematical and had little or no bearing on practical engineering problems. Institute papers are primarily engineering papers, and while mathematics is a most valuable tool of the engineer it is merely a means to an end. Mathematical solutions, however, complete and ingenious, are out of place in the PROCEEINGS unless they lead to conclusions of practical engineering value.

It must be remembered that the Committee can select for publication only such papers as are secured from or through the efforts of the members, and it is obvious that the most effective critic is the one who furnished an acceptable paper of the character he would like to see published in the PROCEEDINGS.

The value of the Institute to the public and to its membership is given to it by its members.

The PROCEEDINGS should not be regarded as a magazine or a handbook which is purchased with the dues paid. It is the journal of *your society* and its value is determined by the sum total of your individual efforts for the general good.

FUTURE SECTION MEETINGS

Chicago.—May 28, 1917. Subject: "Electric Waves".

Detroit-Ann Arbor.—May 25, 1917. Speaker: Prof. H. H. Higbie.

Fort Wayne.—May 10, 1917. Subject: "The Electrical Home".

Spokane.—May 18, 1917. Subject: "Engineering Education".

Digitized by Google

DIRECTORS' MEETING NEW YORK, APRIL 13, 1917

The regular monthly meeting of the Board of Directors was originally scheduled to be held at Schenectady, N. Y., but owing to the cancellation of the Institute meeting which was to have been held in Schenectady, the Directors' meeting was transferred to Institute headquarters in New York City. The meeting was held at the usual date, Friday, April 13, 1917, at 3:00 p. m.

There were present: President H. W. Buck, New York; Past-President John J. Carty, New York; Vice-Presidents C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., William McClellan, New York, B. A. Behrend, Boston, Mass., L. T. Robinson, Schenectady, N. Y.; Managers, Bancroft Gherardi, A. S. McAllister and F. B. Jewett, New York, John B. Taylor, Schenectady, N. Y., Harold Pender, Philadelphia, Pa., C. E. Skinner, Charles Robbins, Pittsburgh, Pa., N. A. Carle, Newark, N. J.; Treasurer George A. Hamilton, Elizabeth, N. J. and Secretary F. L. Hutchinson.

The action of the Finance Committee in approving monthly bills amounting to $8013.37 was ratified.

Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 79 Students were ordered enrolled, 184 applicants were elected to the grade of Associate, 4 applicants were reinstated to the grade of Associate, one applicant was reinstated to the grade of Member, 13 applicants were elected to the grade of Member, 3 applicants were transferred to the grade of Member, and one applicant was transferred to the grade of Fellow.

Upon the recommendation of the Chairman of the Committee on Student Branches, authority was granted for the organization of a Student Branch at the Massachusetts Institute of Technology, Cambridge, Massachusetts.

The question whether or not, in view of the war, it would be advisable to recommend any change in the arrangements for the Annual Convention was discussed, and the Board decided to adhere to the dates and location previously decided upon; namely, Hot Springs, Virginia, June 26-29, 1917.

A considerable amount of other business was transacted, reference to which will be found in this and future issues of the PROCEEDINGS.

PAST SECTION MEETINGS.

Atlanta.—March 8, 1917, Chamber of Commerce. Election of officers for the coming year as follows: Chairman, A. M. Schoen; vice-chairman, E. P. Peck; secretary, Thomas C. Talliaferro.

March 16, 1917, Chamber of Commerce. Address by Major Lytle Brown, U. S. Engineer Corps, on "The Organization, Purpose and Scope of the U. S. Engineer Reserve Corps." Also brief addresses by Messrs. J. A. Yundt, Charles W. Stone and A. M. Schoen. Attendance 285.

Boston.—March 8, 1917, Franklin Union. Illustrated address by Mr. W. B. Potter on "Electric Transmission for Motor Cars." Attendance 350.

April 3, 1917, Franklin Union. Illustrated addresses by Captain F. E. Williford, Coast Artillery Corps, and Captain S. B. Downing, Engineering Corps, on "Duties of the Engineer in Time of War." Attendance 350.

Chicago.—March 26, 1917, Western Society of Engineers. Paper: "The Financial Plan of the Report of the Chicago Traction and Subway Commission" by Bion J. Arnold. Attendance 200.

Cleveland.—February 26, 1917, Electrical League, Hotel Statler. Paper: "Central Stations Share in Industrial Development" by H. L. Wallau. Brief addresses by Messrs. Wallau, Lindstrom and Rakestraw on National Preparedness and the Part to be Taken by the Engineer. Attendance 50.

Digitized by Google

April 16, 1917, Electrical League Rooms, Hotel Statler. Address by Mr. Ben Perris on "Illuminating Engineering in the Motion Picture Industry." Joint meeting with Pittsburgh Section, I. E. S.

Denver.—March 17, 1917, Denver Athletic Club. Paper: "The Electric Furnace" by R. M. Keeney. Addresses by Dr. R. B. Moore and Mr. Thos. B. Stearns, Chairman and member respectively of the Colorado State Board of Directors of the Naval Consulting Board, on "Industrial Preparedness." Attendance 60.

Detroit-Ann Arbor.—February 23, 1917. Paper: "Direct-Current Motors" by J. C. Parker. Attendance 21.

March 9th, 1917, Detroit Engineering Society Rooms. Paper: "Electric Arc Welders" by J. F. Lincoln. Attendance 125.

Fort Wayne.—March 8, 1917, Temple Theatre. Moving picture "King of the Rails." Attendance 1500.

April 12, 1917, Anthony Hotel. Illustrated lecture by Mr. W. B. Potter on "Electrification of the Chicago, Milwaukee and St. Paul R. R." Attendance 50.

Indianapolis-Lafayette.—March 16, 1917, Indianapolis. Paper: "The Largest Meter for the Largest Plant in the World." by D. H. Angus. Attendance 70.

Ithaca.—March 31, 1917. Papers: (1) "The Electrical Features of the Panama Canal" by G. D. Stahl; (2) "The Problems and Possibilities of the Central Station Industry" by T. G. Spates. Attendance 35.

Kansas City.—March 28, 1917, Lawrence, Kansas. Illustrated lecture by Prof. A. S. Langsdorf on "The Heating of Transformers." Motion picture "King of the Road." Attendance 96.

Los Angeles.—March 27, 1917, Chamber of Commerce. Paper: "Indexing of Engineering Data" by James E. Barker. Attendance 35.

Madison.—April 9, 1917, Engineering Building. Symposium on "Transmission Line Insulators" by Messrs. G. C. Neff, H. M. Crothers and G. H. Gray. Attendance 40.

Milwaukee.—April 11, 1917, City Club. Illustrated address by Mr. W. M. White on "Modern Hydraulic Turbines—A Milwaukee Product." Attendance 70.

Pittsburgh.—March 13, 1917, Eng. Society of Western Penna., Paper: "Power Limiting Reactances and Service Protection" by A. R. Cheyney. Attendance 90.

April 10, 1917, Eng. Society of Western Penna., Paper: "Voltage Regulation of Large Transmission Systems" by J. E. Thomas, E. C. Stone and H. L. Fullerton. Attendance 65.

Pittsfield.—March 14, 1917, Hotel Wendell. Eighth Annual Dinner, followed by Address by Mr. Samuel Insull on "Some Developments in Public Utility Operations." Attendance 242.

March 29, 1917, Hotel Wendell. Paper: "Insulating Materials" by L. E. Barringer. Attendance 115.

Portland.—March 6, 1917, Multnomah Hotel. Paper: "Steam Turbines and Reduction Gears for Ship Propulsion," by W. J. Davis. Attendance 180.

April 3, 1917, Multnomah Hotel. Paper: "A Field Investigation of Inductive Interference in Telephone Circuits Arising from Parallelism with a 55,000-Volt Power Circuit" by R. W. Mastick. Attendance 41.

San Francisco.—February 23, 1917, Engineers' Club. Paper: "Maximum Demand Meters" by W. A. Hillebrand. Attendance 70.

March 23, 1917, Engineers Club. Paper: "The Manufacture of Incandescent Lamps" by J. A. Vandegrift. Attendance 50.

Seattle.—March 20, 1917. Paper: "Combined Steam and Hydroelectric Operation", by J. D. Ross. Attendance 41.

Spokane.—March 16, 1917, Paper: "Recent Developments in Electrical

Digitized by Google

Cooking", by Miss Laura Addison. Attendance 75.

St. Louis.—March 28, 1917, Engineers Club. Illustrated address by Mr. H. Weichsel on "Characteristics and Applications of Various Types of Polyphase Motors". Attendance 57.

Toronto.—March 16, 1917, Engineers Club. Illustrated address by Mr. Henry W. Fisher on "Underground Cables". Attendance 60.

Washington.—March 6, 1917, Bureau of Standards. Address by Prof. Michael I. Pupin on "Selective Electrical Transmission". Attendance 113.

PAST BRANCH MEETINGS

University of Arkansas.—April 2, 1917. Paper: "Hydroelectric Development" by Guy Irby. Attendance 12.

Armour Institute. March 27, 1917. Paper: "Distribution of Central Station Energy through Substations," by E. W. Grover. Attendance 21.

Polytechnic Institute of Brooklyn.—March 21, 1917. Mailloux Library. Illustrated lecture by Mr. E. E. Bucher on "Wireless Telegraphy" Atendance 35.

March 24, 1917. Inspection Trip to the Gold Street generating station of the Edison Electric Illuminating Company of Brooklyn. Attendance 30.

March 30, 1917, Mailloux Library. Addresses as follows:—(1) "Operation of Lighting Substations" by Robert Davie; (2) "Converter Starting by Direct Current" by V. R. Wall; (3) "Selenium, its Properties and Applications", by S. Cohen, Attendance 21.

University of California.—March 14, 1917. Address on "The Efficiencies of the Small Pelton Water Wheels Tested in our Hydraulics Laboratory". Address by Prof. J. H. Hildebrandt on "Culture for Engineers". Attendance 28.

March 28, 1917. Illustrated address by Mr. Potts on "The Manufacture and the Uses of Ball Bearings in the Present Day". Attendance 24.

Carnegie Institute of Technology.—March 21, 1917. Paper: "Industrial Control", by H. D. James. Attendance 40.

Clarkson College.—February 14,1917. Paper: "Engineering Accounting," by Paul B. Murphy. Attendance 21.

February 28, 1917. Paper: "Regenerative Braking of Electric Vehicles," by R. E. Hellmund. Attendance 15.

April 4, 1917. Papers: (1) "Retardation of Automobiles," by R. M. La Clair (2) "Commercial Engineering," by H. H. Plank. Attendance 12.

University of Colorado.—February 15, 1917. Engineering Building. Paper: "Theory and Practise in Electrical Engineering," by C. E. Drennan. Attendance 18.

Iowa State College.—March 14, 1917. Address by Mr. E. L. Fischer on "The Need of Cooperation between Public Utilities and Municipalities". Attendance 34.

March 21, 1917. Illustrated lecture by Mr. A. B. Cole on "The Electrification of Steam Railroads". Attendance 84.

University of Kansas.—March 14, 1917, Marvin Hall. Papers: (1) "The Corona Voltmeter," by F. H. Fox; (2) "Manufacture of Munitions," by H. J. Gish. Attendance 38.

March 28, 1917, Marvin Hall. Annual Meeting. Papers: (1) "Geared Turbine Units," by C. H. Taylor; (2) "Electric Propulsion of Ships," by C. K. Capp; (3) "The Heating of Transformers," by A. S. Langsdorf; (4) "The Manufacture of Nitrogen from the Air," by H. P. Cady; (5) "Public Utility Service," by J. T. Skinner; (6) "The Progress of Electrical Development," by F. B. Uhrig. Joint meeting with Kansas City Section. Attendance 98.

April 12, 1917, Marvin Hall. Addresses as follows:—(1) "Street-Car Street Indicator" by H. F. Lutz; (2) "Carbon Brush Testing," by A. V. Forsythe. Attendance 35.

Digitized by Google

Lehigh University.—March 22, 1917, Physics Lecture Room. Papers: (1) "A Municipal Hydroelectric Lighting Plant for Asheville, N. C.", by H. E. McDowell; (2) "Methods of Carrying on Central Station Business," by A. H. Cantlin. Attendance 44.

Lewis Institute.—March 28th, 1917. Paper: "Electrons and How They Serve Us," by W. C. Bauer. Attendance 412.

University of Michigan.—March 1, 1917, New Engineering Building. Paper: "Induction Motors as Applied to Battleships," by A. M. Dudley. Attendance 79.

March 26, 1917, New Engineering Building. Illustrated lecture by Mr. S. L. Crump on "Air-Break Circuit Breakers". Attendance 28.

University of Missouri.—April 2, 1917, Engineering Building. Paper: "Coke Ovens and By-Products," by M. K. Varner. Attendance 20.

April 11, 1917, Engineering Building. Paper: "Public Service," by H. B. Shaw. Attendance 49.

University of North Carolina.—March 29, 1917. Paper: "Panama Canal and Its Electrification," by Thomas W. Strange. Attendance 15.

Ohio Northern University.—March 28, 1917, Dukes Memorial. Lecture by Prof. K. B. McEacheron on "Alternating-Current Waves," demonstrated with an oscillograph. Attendance 43.

Ohio State University.—March 23, 1917, Robinson Laboratory. Address by Mr. F. W. Gilchrist on "The Corona Voltmeter". Attendance 22.

April 13, 1917, Robinson Laboratory. Paper: "Determining the Value of Public Utilities," by A. E. Flowers. Attendance 29.

University of Oklahoma.—March 13, 1917, Engineering Building. Paper: "Heaviside Operators and Oscillating Current Circuits," by A. Press. Attendance 26.

April 10, 1917, Engineering Building. Paper: "Private Ownership of Electrical Utilities," by J. A. Wheatley. Debate: Resolved that Oklahoma City Should Have a Municipally Owned Central Station. Affirmative: A. M. Pigg. Negative: A. E. Erickson. Decision given to affirmative. Attendance 18.

Oregon Agricultural College.—March 29, 1917. Address by Messrs. Hildreth and Zimmerman on their experiences in electrical work. Attendance 22.

University of Pittsburgh.—March 20, 1917, Thaw Hall. Illustrated lecture by Mr. L. A. Riddell on "Electrification of the Chicago, Milwaukee and St. Paul R. R.". Attendance 75.

Purdue University.—March 20, 1917, Electrical Building. Illustrated lecture by Prof. C. F. Harding on "Insulation of High-Voltage Transmission Lines". Attendance 78.

March 27, 1917, Electrical Building. Paper: "Street Lighting Development," by A. N. Topping. Attendance 55.

Rensselaer Polytechnic Institute.—April 10, 1917, Sage Laboratory. Illustrated lecture by Mr. A. D. Colvin on "The Opportunities for Technical Graduates in Public Service Corporations". Attendance 40.

Syracuse University.—March 29, 1917. Address by Mr. D. J. Burke on "The Crucible and Electric Furnace Methods of Manufacturing High Grade Steel—and Rolling Mill Methods". Attendance 14.

April 12, 1917. Illustrated lecture by Mr. H. R. Klumbach on "Color Photography". Attendance 16.

Throop College of Technology.—March 22, 1917, Pasadena Hall. Illustrated address by Mr. G. A. Reichard on "Engineering Work in Japan". Attendance 40.

April 5, 1917, Pasadena Hall. Address by Mr. Earle S. Ovington on "Personal Reminiscences of a Bird Man". Attendance 117.

Washington State College.—March 2, 1917. Lecture on "Regenerative Brak-

Digitized by Google

ing," by Mr. J. W. Byers. Attendance 27.

March 16, 1917. Lecture by Prof. C. C. Todd on "Bakelite". Attendance 14.

Washington University.—April 12, 1917, Cupples Hall. Paper: "Newer Mazda Lamps and Some of Their Applications". Attendance 15.

ASSOCIATES ELECTED APRIL 13, 1917

ADAMS, RALPH B., Telephone Engineer, U. S. Forest Service; res., 437 Eddy Ave., Missoula, Mont.

ALTLAND, COMER P., Efficiency Clerk, Pacific Gas & Electric Co., 226 Jessie St.; res., 662 Clayton St., San Francisco, Cal.

*ANDERSON, OSCAR VICTOR, Superintendent of Distribution, Toronto Electric Light and Toronto Railway Co., res., 535 Shaw St., Toronto, Ont.

ASHLEY, ALLEN, Sales Engineer, Westinghouse Electric & Mfg. Co., 165 Broadway, New York; res., 190 Archer St., Mt. Vernon, N. Y.

ATMORE, ALFRED LAWS, Chief Clerk, Engineering Dept., Philadelphia Electric Co., 1000 Chestnut St.; res., 5241 N. 13th St., Philadelphia, Pa.

AUGUSTINE, PAUL, Special Investigator of Elec. Equipment on Buildings, New York Industrial Education Survey Committee; res., 2381 Valentine Ave., New York, N. Y.

BABBIT, LOUIS ANGELL, Telephone Engineering, Bell Telephone Co. of Pennsylvania, 1631 Arch St., Philadelphia, Pa.

BAILEY, RAYMOND, Power Plant Construction, Philadelphia Electric Co.; res., West Branch Y. M. C. A., Philadelphia, Pa.

BARROW, GEORGE MADARA, Electrical Testing, Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 762 Franklin Ave., Wilkinsburg, Pa.

BAUGH, CLIVE EVERETT, Electrician, Pacific Gas & Electric Co., 445 Sutter St., San Francisco; res., Campbell, Cal.

BEMAN, RANSOM HAY, Division Equipment Inspector, Western Union Telegraph Co., 511 Healy Bldg.; res., 29 Colguett Ave., Atlanta, Ga.

BENNECHE, HALVOR WILLARD, Foreman Station Construction, Anaconda Copper Mining Co.; res., 1309 7th Ave. No., Great Falls, Mont.

BENNINGTON, EARL THOMAS, Salesman, Erner Electric Co.; res., 11802 Tuscora Ave., Cleveland, O.

BERG, E.E., System Operator, Washington Water Power Co., Spokane, Wash.

*BERGMAN, DONALD JOSEPH RUSSELL, Instructor in Electrical and Mechanical Engineering, University of Santa Clara; res., 660 Lafayette St., Santa Clara, Cal.

*BILLHEIMER, CYRUS RAYMOND, Electrical Engineering Dept., West Penn Power Co., Pittsburgh; res., 411 Rebecca Ave., Wilkinsburg, Pa.

BLAKESLEY, GEORGE R., Superintendent and Manager, Baraboo Station, Wisconsin Power, Light & Heat Co., 400 Oak St., Baraboo, Wis.

BOND, FRANCIS MARVIN, Industrial Engineer, Philadelphia Electric Co.; res., 3607 Chestnut St., Philadelphia, Pa.

BONINE, J. H., Field Engineer, Lewis & Roth Co., 1012 Liberty Bldg., Philadelphia; res., Highland Park, Pa.

BOTHWELL, JOHN HOWARD, President and General Manager, Bothwell Electric Co., 15 Spring Common; res., 127 W. Myrtle Ave., Youngstown, O.

BRAUN, WILLIAM, Contracting Electrical Engineer, 50 Church St., New York; res., 494 Manor Ave., Brooklyn Manor, L. I., N. Y.

BROUN, LAFORA EUGENE, Assistant System Operator, Public Service Co. of Northern Illinois; res., 506 Western Ave., Joliet, Ill.

BROWN, JOHN TUNISON, Foreman, Station constructing electricians, Pacific Gas & Electric Co.; res., 1276 Jones St., San Francisco, Cal.

Digitized by Google

BYRNE, WALTER S., Industrial Engineer Omaha Electric Light & Power Co.; res., 707 New Hamilton Apts., Omaha, Neb.

CAMPBELL, WILLIAM THOMAS, Wagner Electric Mfg. Co., 1650 Real Estate Trust Bldg., Philadelphia, Pa.; res., 635 Cherrier Pl., Camden, N. J.

CARTER, OSCAR SEDGEWICKE, Assistant to Combustion Engineer, United Gas Improvement Co., 1401 Arch St., Philadelphia; res., Cynwyd, Pa.

CARTMELL, RYALL HERBERT, Electrician, Detroit Edison Co.; res., 17 Brady St., Detroit, Mich.

CARTWRIGHT, ALLEN NORTH, General Superintendent Transmission, West Penn Power Co., 4th Ave., Pittsburgh, Pa.

CASTLEMAN, DAVID JAMES, Assistant Engineer, Gibbs & Hill; res., 157 W. 123rd St., New York, N. Y.

CHAPPELL, WILLIAM HAROLD, Laboratory Assistant, Philadelphia Electric Co.; res., 233 Roxboro Ave., Philadelphia, Pa.

*CHEENY, RICHARD CLARK, Automobile Sales, Medina; res., LeRoy, O.

CHRISTIANSEN, KAJ CHRISTIANS, Assistant Electrical Engineer, International Acheson Graphite Co.; res., 913 Walnut Ave., Niagara Falls, N. Y.

*CLAPP, PAUL SPENCER, Western Electric Co., New York, N. Y.; res., 27 Hillside Ave., Montclair, N. J.

CLARK, WALTER JOHN, Engineer of Equipment and Maintenance, General Electric Co.; res., 66 Springside Ave., Pittsfield, Mass.

CORDES, WILLIAM BERNARD, Electrical Construction Foreman, General Electric Co.; res., 503 W. 169th St., New York, N. Y.

COX, HARRY A., Chief Operating Engineer, Orange County Lighting Co.; res., 119 W. Main St., Middletown, N. Y.

COX, JOHN W., Maintenance Man, Appalachian Power Co., Bluefield, W. Va.

CURRY, WALTER ANDREW, Junior Asst. to Chief Electrical Engineer, New York, Edison Co., 124 E. 15th St., New York, N. Y.

*CURTIS, RALPH ENDICOTT, Assistant Electrical Engineer, United Electric Light Co., Springfield; res., 202 Ohio Ave., West Springfield, Mass.

DANE, H. P. LOUIS, Electrical Engineer, Research Corporation, New York; res., 144 Columbia Heights, Brooklyn, N. Y.

*DAVIES, JAMES BENFORD, JR., Engineer, Alabama Power Co.; res., 1309 Glen Iris Ave., Birmingham, Ala.

*DEMING, GEORGE EDWARD, Engineering Assistant, Counties Gas & Electric Co., 120 West Penn St., Norristown, Pa.

*DEWARS, ALLEN GUTHRIE, St. Paul Gas Light Co., St. Paul; res., 3241 Minnehaha Ave., Minneapolis, Minn.

DODD, SAMUEL MORRIS, Sales Engineer, Wagner Electric Mfg. Co., 1650 Real Estate Trust Bldg., Philadelphia; res., 116 Yale Ave., Swarthmore, Pa.

DODGE, WALTER J., Engineer, Pacific Tel. & Tel. Co., San Francisco; res., 1120 Ventura St., Berkeley, Cal.

DOLBIER, FRED. E., Electrical Engineer, Walker & Kepler, 531 Chestnut St., Philadelphia; res., 43 W. Stratford Ave., Lansdowne, Pa.

DREW, ERNEST CLAUDE, Engineering Dept., Bell Telephone Co. of Pennsylvania, 1631 Arch St.; res., 519 S. 42nd St., Philadelphia, Pa.

DUDLEY, NOLAN LEWIS, JR., Electrical Engineer, Empire Steel & Iron Co., Mt. Hope, N. J.

*DUMOND, JESSE WILLIAM MONROE, Testing Dept., General Electric Co.; res., 17 Elm St., Schenectady, N. Y.

DUNN, STEPHEN E., Electrical Student, University of California, 2333 Channing Way, Berkeley, Cal.

EALES, HERBERT WILLIAM, Chief Electrical Engineer, Union Electric Light & Power Co.; res., 3927 Shaw Ave., St. Louis, Mo.

EILERS, ROY M., Counsel for Electrical Manufacturing Companies, 824 Central National Bank Bldg.; res., 1616 Kings Highway, St. Louis, Mo.

ELLIOTT, EDWARD BYRON, Engineer, Semet-Solvay Co.; res., 942 Westcott St., Syracuse, N. Y.

Digitized by Google

ELLIS, JOHN WINTHROP, Hydraulic Operator, Mt. Whitney Power & Electric Co., Hammond; res., 1014 Myrtle St., Oakland, Cal.

ELLIS WALTER CARROLL, Superintendent of Lines, Westfield Gas and Electric Light Works; res., 44 Court St., Westfield, Mass.

EPPS, WILLIAM JAMES, Electrical Engineer, Rua Dom Geraldo 80, Rio de Janeiro, Brazil, South America.

*EPSTEIN, SOLOMON ALEXANDER, Electrical Contracting and Sales Engineer, X-L Electric Co.; res., 237 Race St., Philadelphia, Pa.

FLEMING, ASHER KESBY, Chief Chassis Electrician and Experimental Engineer, Simplex Automobile Co.; res., 78 Jersey Ave., New Brunswick, N. J.

FORSGARD, CHARLES HENRY, Division Manager, Texas Gas & Electric Co., Childress, Tex.

FOURAKER, LEROY L., Inspector, Philadelphia Electric Co.; res., 1625 Allengrove St., Philadelphia, Pa.

FRAZIER, BAYARD RHODES, Transformer Engineering Dept., General Electric Co.; res., Pontoosuc Lake, Pittsfield, Mass.

FULLER, HARRY LAWRENCE, Assistant Superintendent, Electric Co. of Missouri and St. Louis Co. Gas Co., 6170 Bartmer Ave., St. Louis, Mo.

*FUNK, RAYMOND J., Engineer, Service Dept., Brown Instrument Co., 2138 Oliver Bldg., Pittsburgh; res., 5029 Haverford Ave., Philadelphia, Pa.

GALAJIKIAU, HAIG, Engineer, Commonwealth Edison Co., 28 N. Market St.; res., 5916 Kenmore Ave., Chicago, Ill.

*GAUSS, WILLIAM F., Supervisor of Methods, Central District Telephone Co.; res., 5510 Ellsworth Ave., Pittsburgh, Pa.

GOLDSCHMIDT, A. L., Electrical Engineer, Secretary - Treasurer, Public Utilities Corp., Malta, Mont.

GOLL, WALTER SCOTT, Commercial Engineer, General Electric Co., Fort Wayne, Ind.

GOMEZ, LOUIS GRANT, Telephone Expert, Public Utilities Commission of the State of Colorado, 210 Telephone Bldg., Denver, Colo.

GOODNOW, FRANK EDWARD, Engineer of Electrical Design, Public Service Co., 72 W. Adams St., Chicago, Ill.

GREEN, HENRY HOLMES, Electrical Asst., Testing Bureau, Brooklyn Rapid Transit System; res., 42 Irving Pl., Brooklyn, N. Y.

GREGG, ALBERT MERVIN, Engineer, Electrical Construction, Great Western Sugar Co., 600 Sugar Bldg.; res., 1048 Downing St., Denver, Colo.

GROSSMAN, PHILIP, General Manager, Vaughn & Meyer, 1007 Majestic Bldg.; res., 520 Lake Drive, Milwaukee, Wis.

HAGENSICK, EDMUND HERBERT, Superintendent Electrical Line, Omaha and Council Bluffs Street Ry. Co., Omaha, Neb.

HAINES, LLOYD, Assistant to Electrical Engineer, A. C. Wood; res., 886 Holly St., Philadelphia, Pa.

*HAINES, WILLIAM HOWARD, Electrical Engineer, Westinghouse, Church, Kerr & Co., 37 Wall St.; res., 782 West End Ave., New York, N. Y.

HALE, WILLIAM KING, Assistant to Electrical Engineer, Mountain States Tel. & Tel. Co.; res., 1430 Franklin St., Denver, Colo.

HALL, HARRY G., District Agent, Detroit Edison Co.; res., 16 Mosher Pl., Mt. Clemens, Mich.

HALL, LYNDON THOMAS, Asst. Supt. Construction, Lewis & Roth Co., 1012 Liberty Bldg.; res., 18 S. 43rd St., Philadelphia, Pa.

HARBAUGH, WILLIAM MILTON, Efficiency Engineer, Kansas City Light & Power Co.; res., 4020 Walnut St., Kansas City, Mo.

HAROLD, JOHN J., Power Station Equipment and Printing Plant; res., 64 W. 107th St., New York, N. Y.

HART, R. DEAN, Electrical Mechanic, Washington Water Power Co.; res., W. 2128 Mallon Ave., Spokane Wash.

Digitized by Google

HAYES, JOHN MAURICE, Transformer Specialist, Philadelphia District Office General Electric Co., Witherspoon Bldg., Philadelphia, Pa.

HAZZARD, ROY THORPE, Hydraulic Operator, Mt. Whitney Power & Electric Co., Hammond; res., Whittier, Cal.

HEINRITZ, WALTER JOHN, Construction Engineer, United Gas Improvement Co., Philadelphia; res., "The Hamilton", Norristown, Pa.

HENNESSEY, MAURICE JOHN, Chief Draftsman, Lewis & Roth Co., 1012 Liberty Bldg.; res., 5012 Wayne Ave., Germantown, Philadelphia, Pa.

HERSH, HARRY, Sales Engineer, Milwaukee Electric Railway & Light Co.; res., 491½ 34th St., Milwaukee, Wis.

HILLEMEYER, JOSEPH EDWARD, Supt. of Gas and Electrical Distribution, Union Electric Light & Power Co.; res., 52 Jefferson Barracks Rd., Webster Groves, Mo.

HORNBERGER, EARL J., Sales Engineer, Wagner Electric Mfg. Co., 1650 Real Estate Trust Bldg., Philadelphia, Pa.; res., 209 Penn St., Camden, N. J.

HOYE, JAMES PERNELL, Mechanical and Electrical Engineer, National Twist Drill & Tool Co., Brush & Grand Blvd.; res., 797 Seneca Ave., Detroit, Mich.

HUBBELL, JAMES WAKEMAN, Engineer of Equipment and Buildings, Bell Telephone Co. of Pennsylvania, 1631 Arch St., Philadelphia, Pa.

INGHAM, CLARENCE RAY, General Foreman, Iowa Electric Co., Cedar Rapids; res., Toledo, Ia.

JANSEN, EDWARD CLINTON, Chief Engineer, Colorado Power Co., 828 Symes Bldg.; res., 1145 Lafayette St., Denver, Colo.

JENKINS, JOHN EDGAR, Switchboard Operator, Philadelphia Electric Co.; res., 2135 S. Frazier St., Philadelphia, Pa.

JOHNSON, CHARLES FRANKLIN, Virginia Railway & Power Co., 505 E. Grace St., Richmond, Va.

JOHNSON, JOHN HENRY, Manager of Sales and Estimating Depts., Messrs. Crompton & Co. Ltd.; res., "Trewedna", Park Ave., Chelmsford, England.

JOHNSON, LEO C., Electrical Mechanic, Washington Water Power Co.; res., E. 803 Bridgeport Ave., Spokane, Wash.

JONES, PAUL SCOTT, Electrical Engineer, Cutler-Hammer Mfg. Co.; res., 183 14th St., Milwaukee, Wis.

JOYCE, JOHN BERNARD, JR., New Business Assistant to the Agent, Public Service Electric Co., 695 Bloomfield Ave., Montclair, N. J.

KAUMHEIMER, EDWIN A., Milwaukee Electric Railway & Light Co.; res., 987 2nd St., Milwaukee, Wis.

KNOWLES, WILLIAM, Electrician, El Paso Smelting Works, El Paso, Tex.

KOCH, HERMAN J., Draftsman, Cutler-Hammer Mfg. Co.; res., 485 39th St., Milwaukee, Wis.

*KRESSLY, HOWARD CHARLES, Station Construction Dept., Philadelphia Electric Co.; res., 1752 N. Marshall St., Philadelphia, Pa.

LARIVIÈRE, ALEXANDRE, Electrical Engineer, Quebec Public Utilities Commission; res., 65 St. Ann St., Quebec, Que.

LITTLE, EDWARD WHITNUM, Electrical Draughtsman, Interborough Rapid Transit Co.; res., 5000 Broadway, New York, N. Y.

LOUDEN, JAMES GRAVES, Sales Engineer Engineering Equipment Co.; res., 6227 Ogontz Ave., Philadelphia, Pa.

*LUCAS, HARRY NYE, Salesman, Westinghouse Electric & Mfg. Co., Philadelphia; res., 6 Benedict Ave., South Ardmore, Llanerch, Pa.

MAC GILLIVRAY, Howard, Sales Engineer, Cutler-Hammer Mfg. Co., 50 Church St., New York; res., 93 N. 13th St., Flushing, N. Y.

MANCHA, RAYMOND, President, Mancha Storage Battery Locomotive Co., 1941 Railway Exchange Bldg., St. Louis, Mo.

Digitized by Google

*MARKLEWITZ, EMIL ALBERT, Commercial Engineer's Office, Mountain States Tel. & Tel. Co.; res., 4106 Stuart St., Denver, Colo.

MATHEWS, CLARENCE EUGENE, Foreman Construction, Lewis & Roth Co., 1012 Liberty Bldg., Philadelphia, Pa.

MATTHEWS, IRA BURNARD, Supt., Transformer Dept., Toledo Railways & Light Co.; res., 426 Langdon St., Toledo, O.

MCDONALD, DONNELLY PATRICK, Factory Engineer, General Electric Co.; res., 536 W. Jefferson St., Ft. Wayne, Ind.

MCFARLAND, HEBER, Sales and Engineering, National Carbon Co.; res., 11020 Detroit Ave., Cleveland, O.

*MCIVER, MATTHEW GILMOUR, Draftsman, Engine Div., Newport News Shipbuilding & Dry Dock Co.; res., 91 32nd St., Newport News, Va.

MCLEOD, WALTER R., Division Power Representative, Public Service Electric Co., 84 Sip Ave.; res., 25 Jones St., Jersey City, N. J.

MEYERS, WILLIAM H., Superintendent, Stations and Lines, Bridgeton Electric Co.; res., 36 Washington St., Bridgeton, N. J.

MITCHELL, WILLIAM ANGUS, Electrical Engineer, Great Western Sugar Co., 500 Sugar Bldg.; res., 2939 Douglas Pl., Denver, Colo.

MOORE, ROBERT VERNON, Chief Engineer, Armour Leather Co.'s Extract Plant, Sylva, Jackson County, N. C.

NAKAGAWA, TOKURO, Chief Engineer, Okumura Electric Co.; Lecturer, Kyoto Imperial University; res., 3 Dekuchi Shogoincho, Kyoto, Japan.

NEEL, WILLIAM TRENT, Asst. to Supt. of Meter and Installation Depts., Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

NESBITT, FREDERICK COOKMAN, Engineer, E. W. Clark & Co. Management Corp., Huntington Bank Bldg., Columbus, O.

NEVRAUMONT, LOUIS JOSEPH, Operator, Pacific Gas & Electric Co.; res., 197 Duboce Ave., San Francisco, Cal.

NICHOLS, JOSEPH BARSTOW, Superintendent, Paulsen Building; res., 04009 Calispell, Spokane, Wash.

NORDFELDT, HENRIK BEIGER ELIS, Patent Expert, Allmanna Svenska Elektriska Aktiebolaget, Vasteras, Sweden.

NOSEK, LOUIS F., Chief Meter Tester, Municipal Light Plant; res., 2245 E. 82nd St., Cleveland, O.

NUGENT, FRANK R., Chief Plan Examiner, Department Water Supply, Gas & Electricity; res., 1260 Hamilton Ave., Richmond Hill, N. Y.

OLSEN, BERNHARD, Sales Agent, General Electric Co., 402 Paulsen Bldg.; res., Altadena Apts., Spokane, Wash.

OLSEN, HARRY NORRIS, Testing Dept., Safety Insulated Wire & Cable Co., Bayonne, N. J.; res., 211 W. 47th St., New York N. Y.

ONG, CARLETON G., Salesman, Westinghouse Electric & Mfg. Co., 407 Traction Terminal Bldg., Indianapolis, Ind.

OTT, ERNEST H., Salesman, Westinghouse Electric & Mfg. Co., Cleveland; res., 98 Carlyon Rd., E. Cleveland, O.

PALME, ARTHUR, Transformer Engineering Dept., General Electric Co.; res., Woodlawn Inn, Pittsfield, Mass.

*PARMENTER, ROBERT JOHN, Electrical Draftsman, Sargent & Lundy; res., 2308 Cleveland Ave., Chicago, Ill.

PATITZ, GEORGE JOHN, Electrical Engineer, Dept. of Gas and Electricity, City of Chicago; res., 4826 N. Monticello Ave., Chicago, Ill.

PAUSTIAN, FRANZ HENRY, Facilities Dept., Nebraska Telephone Co.; res., 114 S. 42nd St., Omaha, Neb.

PERKINS, ROWAN PENROSE, Engineer's Dept., United Gas Improvement Co., 1401 Arch St.; res., 2005 De Lancey St., Philadelphia, Pa.

PERLEY, FRANK G., Assistant Power Engineer, Lehigh Valley Light & Power Co.; res., 36 N. 13th St., Allentown, Pa.

PIKE, PHILIP H., Foreman, Switchboard Dept., Lewis & Roth Co.; res., 2447 Reese St., Philadelphia, Pa.

Digitized by Google

POMEROY, GEORGE AUGUSTUS, Instructor in Electrical Engineering, University of Michigan; res., 836 E. University Ave., Ann Arbor, Mich.

PONSONBY, AMOS A., Assistant Electrical Superintendent, Wilmington Steel Co.; res., 1304 W. 7th St., Wilmington, Del.

PRIOR, HARRY E., Armature Winder, Capital Traction Co.; res., 2408 Pennsylvania Ave., N. W., Washington, D. C.

PROUT, CURTIS, Engineer, Illinois Traction System; res., 513 S. 7th St., Springfield, Ill.

QUAYLE, LE ROY ABELL, Chief Mechanical Engineer, Cleveland Water Department; res., 1455 W. 98th St., Cleveland, O.

QUINTON, T. C., Electrical Engineer, 1166 The Rookery, Chicago; res., 4910 W. 25th St., Cicero, Ill.

RABBE, OSCAR FREDERICK, Superintendent of Heating Station, Toledo Railway & Light Co.; res., 430 Floyd St., Toledo, O.

REDDIE, WILLIAM WALLACE, Sales Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.; res., Columbian Hotel, Trinidad, Colo.

RHODES, SAMUEL ARTHUR, Transmission Engineer, Central Group Bell Telephone Cos., 212 W. Washington, St., Chicago, Ill.

RITTER, WILLIAM HOWARD, Inspector, Public Service Co. of Northern Illinois; res., 1519 Thorn St., Chicago Heights, Ill.

ROBERTS, EDWARD ALEXANDER, Research Fellow, Engineering Experiment Sta., University of Illinois, 114 Transportation Bldg., Urbana, Ill.

ROBERTS, WILLIAM SAUNDERS, Sales Manager, Anderson Motor Co., Rock Hill, S. C.

ROSS, JAMES HARVEY, Electrical Engineer, Freeport Sulphur Co., Freeport, Tex.

SARGL, GOTHARD, Superintendent of Construction, Stone & Webster Construction Co., 147 Milk St., Boston, Mass.; res., East Grand Forks, Minn.

SAUNDERS, GEORGE ALFRED, Electrical Engineer, Station Designing, Hydroelectric Power Commission; res., 42 Major St., Toronto, Ont.

SAUNDERS, LLEWELLYN, Dept. of Standards, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 437 Rebecca Ave., Wilkinsburg, Pa.

SCHNEIDER, FRANCIS JOSEPH, Assistant Switchboard Operator, Philadelphia Electric Co.; res., 2045 S. 19th St., Philadelphia, Pa.

SCHNEIDER, SAMUEL, Foreman Electrician, West End Electric Co.; res., 2835 W. 1st St., Coney Island, N. Y.

SCOTT, MAURICE, Assistant Foreman, Firestone Tire & Rubber Co.; res., 505 Brown St., Akron, O.

*SEARES, LAUREN V., Chief Inspector, Colorado Power Co., 828 Symes Bldg., Denver, Colo.

SHARPLES, A. ROBERTS, Testing Engineer, Electric Service Supplies Co.; res., 1345 71st Ave., Oak Lane, Philadelphia, Pa.

SHURTS, GEORGE JACOB, Electrical Engineer, Standard Underground Cable Co.; res., 101 Madison Ave., Perth Amboy, N. J.

SILBERT, RICHARD HENRY, Special Inspector, Philadelphia Electric Co.; res., 3821 N. 13th St., Philadelphia, Pa.

SILVA, ALBERT D., Commercial Engineer, General Electric Co., 1008 Illuminating Bldg.; res., 1840 E. 26th St., Cleveland, O.

SINELNICK, HARRIS B., JR., Electrical Engineer, Public Service Commission, 1st Dist., 2450 Equitable Bldg., New York, N. Y.

SLOAN, ROYAL DANIEL, Instructor in Electrical Engineering, Montana State College, Bozeman, Mont.

SOMES, HOWARD EDWARD, Chief Draftsman, Automatic Transportation Co.; res., 194 Merrimac St., Buffalo, N. Y.

STEWART, LESTER DOUGLASS, Master Mechanic, Montreal Mining Co., Hurley, Wis.

Digitized by Google

TANN, WALTER LESLIE, Draftsman, D. C. Drafting Dept., General Electric Co.,Schenectady; res., 132 Sixth Ave., North Troy, N. Y.

TAYLOR, ROGER, Engineer, Philadelphia Electric Co.; res., 1120 Tiogo St., Philadelphia, Pa.

*THOMPSON, HAROLD EARLE, JR., Electrical Engineer, Department of Electricity, City of Chicago; res., 2936 Fulton St., Chicago, Ill.

THOMPSON, H. L., Inspector, Royal Indemnity Co., 84 William St., New York, N. Y.; res., 126 State St., Harrisburg, Pa.

THOMSON, GIRARD C., Inspector and Tester, Sperry Gyroscope Co.; res., 745 Argyle Rd., Brooklyn, N. Y.

TIDEMAN, HENRY L. T., Electrical Engineer, 614 City Hall; res., 5625 Windsor Ave., Chicago, Ill.

TOMLINSON, JOSEPH THURMAN, Assistant Chief Electrician, Spang, Chalfant & Co.; res., 618 Butler St., Etna, Pa.

VOLENTINE, PAUL, Power Representative, Public Service Electric Co., 84 Sip Ave.; res., 80 Fairview Ave., Jersey City, N. J.

WALKER, HAROLD NELSON, Electrical Engineer, Washington Water Power Co.; res., 1322 Shannon Ave., Spokane, Wash.

WALKER, HENRY NEWTON, Treasurer, Walker Bros. & Haviland, 112 S. 16th St., Philadelphia; res., Wyncote, Pa.

WARD, GEORGE ADELBERT, Electrical Testing, Cutler-Hammer Mfg. Co.; res., 410 Webster Pl., Milwaukee, Wis.

WARNICK, JOHN HAGEY, Asst. to General Superintendent., United Gas Improvement Co., 1401 Arch St., Philadelphia, Pa.

WATSON, FRANCIS HOBBS, Service Dept. Wagner Electric Mfg. Co.; res., 259 S. 51st St., Philadelphia, Pa.

*WETZEL, WALTER C., Superintendent Water and Light, Borough of Sharpsburg; res., 811 Main St., Sharpsburg, Pa.

*WOODRUFF, BENJAMIN HICKS, JR., Instructor, Electrical Dept., Georgia School of Technology; res., 87 W. North Ave., Atlanta, Ga.

WRIGHT, GEORGE I., Foreman Substation Construction, Southern Pacific Co., 40 Union Station, Portland, Ore.

YATES, PETER BERTRAM, Manager, Hydroelectric Commission of the City of St. Catherines, 200 St. Paul St., St. Catherines, Ont.

ZIMMERMAN, ALFRED W., Manager, Zimmerman Supply Co.; res., 3504 Fairfield Ave., Ft. Wayne, Ind.

ZOLL, ROY CONRAD, Electrical Tester, Bureau of Power and Light, City of Los Angeles; res., 1035 Everett St., Los Angeles, Cal.

Total 184.

*Former enrolled Students.

MEMBERS ELECTED APRIL 13, 1917

BLUM, ARTHUR NORBERT, Chief Engineer, Henry Disston & Sons Inc., Philadelphia; res., The Delmar Morris, Chelton Ave., Germantown, Philadelphia, Pa.

BRYANS, HENRY BUSSELL, Engineer, Counties Gas & Electric Co., 212 DeKalb St.; res., 204 Franklin Ave., Norristown, Pa.

CALDWELL, PAUL, Sales Engineer, General Electric Co., 1315 Oliver Bldg.; res., 7819 Madiera St., Pittsburgh, Pa.

CRISFIELD, J. A. P., Engineer, United Gas Improvement Co., 1401 Arch St.; res., Chestnut Hill, Philadelphia, Pa.

DONALDSON, RODERICK D., Power Engineer, United Gas Improvement Co., 1401 Arch St., Philadelphia; res., 101 Llanfair Rd., Ardmore, Pa.

FRASER, DANIEL MACFARLANE, Estimating Engineer, Canadian General Electric Co. Ltd.; res., 71½ Queen St. East, Toronto, Ont.

IVANOVSKI, GEORGE L., Representative of Russian Siemens-Shuckert Co., 2 Rector St., New York, N. Y.

Digitized by Google

MELLET, JOHN EDWARD, Commercial Engineer, Hydroelectric Sales, Georgia Railway & Power Co.; res. 91 E. 7th St., Atlanta, Ga.

MELNIKOFF, NICHOLAS PAVLOVICH, Chief Engineer, Cabinet of his Majesty, Emperor of Russia; res., Spalernaia, 34, Petrograd, Russia.

OXER, GEORGE CARROL, Supervisor of Design, J. G. White Engineering Corp., New York; res., 23 Sea Ave., Arrochar, S. I., N. Y.

PEABODY, DOUGLASS WELLES, District Manager, Power & Mining Dept., General Electric Co.; res., 247 E. 10th St., Atlanta, Ga.

PENNEY, FRANK HERBERT, Electrical Engineer, Industrial Control Dept., General Electric Co., Schenectady; res., 101 Glen Ave., Scotia, N. Y.

TOMPKINS, EDWARD M., Electrical Engineer, 614 City Hall; res., 1914 Farragut Ave., Chicago, Ill.

ASSOCIATES RE-ELECTED APRIL 13, 1917

FRISBY, ROGER L., Testing Engineer, Commonwealth Edison Co., 28 N. Market St.; res., 3004 Palmer Sq., Chicago, Ill.

HALL, EDWIN CHAMBERLAYNE, Southern Manager, General Acoustic Co.; res., 1657 Lamont St. N. W., Washington, D. C.

HEAD, HARLEY GLENN, Commercial Engineer, General Electric Co.; res., 2423 S. Wayne Ave., Ft. Wayne, Ind.

HILL, HALBERT P., Vice-President and General Manager, Ophüls, Hill & McCreery, Inc., 112-114 W. 42nd St., New York, N. Y.

L'HOMMEDIEU, W. P., Manager, Railway & Lighting Div., Westinghouse Electric & Mfg. Co., 707 First National Bank Bldg., San Francisco, Cal.

MERRILL, BARRETT MORRIS, Assistant Superintendent Light & Power System, Washington Water Power Co.; res., 2315 S. Madison St., Spokane, Wash.

MOORE, NELSON, S., Sales Engineer, Lewis & Roth Co., 1012 Liberty Bldg.; res., 514 Midvale Ave., Philadelphia, Pa.

RANSOPHER, SILAS MILO, Special Agent Vocational Dept. of the Public Schools, Room K, Public Library Bldg., 9th and Locust, Kansas City, Mo.

SMITH, BURKE, Engineering Dept., Central Group of Bell Telephone Cos., Room 1901, 212 W. Washington St., Chicago, Ill.

SMITH, IRVING B., Head of Research Dept., Leeds & Northrup Co., Philadelphia; res., Ambler, Pa.

WILLIAMS, SAMUEL BORTON, Bell Telephone Co. of Pennsylvania, Philadelphia; res., 106 Llandaff Rd., Llanerch, Pa.

MEMBER RE-ELECTED APRIL 13, 1917

BATCHELLER, BIRNEY CLARK, Chief Engineer, American Pneumatic Service Co., New York; res., Hotel Margaret, Columbia Heights, Brooklyn, N. Y.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its regular monthly meeting on April 4, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

SOTHMAN, P. W., Consulting Engineer, New York, N. Y.

To Grade of Member

GROVE, WILLIAM H., Inspector for Electrical Engineer, Edison Electrical Illuminating Co. of Brooklyn, Brooklyn, N. Y.

PANNELL, ERNEST V., Engineer, British Aluminum Co. Ltd., Toronto, Ont.

SMITH, IRVING B., Head of Research Dept., Leeds & Northrup Co., Ambler, Pa.

Digitized by Google

SUTTON, H. CRAIG, Assistant to Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

TOMPKINS, H. K. V., Chief Engineer, Texas Gas & Electric Co., Houston, Tex.

Recommended for Transfer by the Board of Examiners April 26, 1917.

To Grade of Member

JEFFERSON, W. H., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

TRANSFERRED TO THE GRADE OF FELLOW APRIL 13, 1917

HUNT, FRED L., Chief Engineer, Turners Falls Power & Electric Co., Greenfield Electric Light & Power Co., Amherst Gas Co., Easthampton Gas Co., Agawam Electric Co., Ludlow Electric Light Co., Greenfield, Mass.

TRANSFERRED TO THE GRADE OF MEMBER APRIL 13, 1917

DYCHE, HOWARD EDWARD, Assistant Professor of Electrical Engineering, University of Pittsburgh, Pittsburgh, Pa.

MEYER, FRANK J., Chief Electrical Engineer, Oklahoma Gas & Electric Co., Oklahoma City, Okla.

STEVENOT, J. E. HAMILTON, Constructing and Consulting Electrical Engineer, Manila, P. I.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before May 31, 1917.

Abbott, W. R., Chicago, Ill.
Arnett, W. W., Jr. (Member), Philadelphia, Pa.
Bartlett, P. H. (Member), Philadelphia, Pa.
Benton, C. H., Haskell, N. J.
Berkley, H. W., East Pittsburgh, Pa.
Berry, C. M., Bluefield, W. Va.
Biggs, J. E., Chicago, Ill.
Bolle, H. A., New York, N. Y.
Bowles, R. H., Sau Paulo, Brazil
Bradish, C. B. (Member), Schenectady, N. Y.
Breitinger, C. M., Philadelphia, Pa.
Caldwell, B. J. (Member), Champaign, Ill.
Callahan, E., Jr., Cornucopia, Ore.
Chaffe, J. B., Jr., New York, N. Y.
Condon, E. J., Jr., Angola, Ind.
Cooper, S. M., Long Island City, N. Y.
Coulter, R. S., Chicago, Ill.
Cronheim, D. H., Birmingham, Ala.
Cruzat, M. A., East Pittsburgh, Pa.
Cuff, G. C., Toronto, Ont.
Curtis, H. A., Hobart, Tasmania
Custer, W. O. (Member), Mansfield, O.
Dann, N. L., Montreal, Que.
Danser, H. W., Long Branch, N. J.
Davis, A. H., Jr., Schenectady, N. Y.
Davis, A. L., Bangor, Me.
Davis, H. E., Syracuse, N. Y.
Dempster, J. B. (Member), Des Moines, Ia.
Desbecker, J. W., New York, N. Y.
Donahoe, J. T., Chicago, Ill.
Donkin, J., Jr., Chicago, Ill.
Douglas, D. C., Camden, N. J.
Drummond, W. D., Liverpool, O.
Dunlap, C. H., Chicago, Ill.
Ellis, J., Philadelphia, Pa.
FitzGerald, G. G., Oxnard, Cal.
Freeman, H. A. (Member), Ampere, N. J.
Freeman, R. M., Waterbury, Conn.
Friday, E. C., Pittsfield, Mass.
Froebel, G. H., Houston, Tex.
Frye, J. L., Bisbee, Ariz.
Gauthier, W. B. J., Philadelphia, Pa.
Gibbs, A. A., Detroit, Mich.
Glaubitz, H. J., (Member) New York, N. Y.
Googins, W., Allentown, Pa.

Digitized by Google

Green, A. J., Paterson, N. J.
Greene, J. F., Detroit, Mich.
Greenwood, L. H., North Troy, N. Y.
Hadley, J. L., Warren, O.
Hanover, J. W., Collinsville, Conn.
Hauck, E., Newark, N. J.
Healey, F. R., Cincinnati, O.
Heath, H. G., Pittsburgh, Pa.
Hobart, C. M., Houston, Tex.
Hoffman, R. T., Pueblo, Colo.
Horelick, S., Pittsburgh, Pa.
House, B. E., Detroit, Mich.
Howard, B. F. (Member), Denver, Colo.
Hughes, G. A., Chicago, Ill.
Jenks, J. S., Pittsburgh, Pa.
Jones, A. H. (Member), McComb, Miss.
Jones, P. C., Akron, O.
Karn, H. C., Montreal, Que.
Kelly, D. H., New York, N. Y.
Kuylenstjerna, A. (Member), Philadelphia, Pa.
Leisenring, F. S. (Member), New York, N. Y.
Lemp, H. J., Erie. Pa.
Lessey, S. K., Philadelphia, Pa.
Lewis, D. M., Avon, N. Y.
Lovell, W. V., East Pittsburgh, Pa.
Mashburn, W. E., Nacozari, Mex.
Matthews, H. D., Schenectady, N. Y.
McCleery, D. W. (Member), Great Falls, Mont.
McLagan, E. G., St. Louis, Mo.
Metzenheim, H. H., Ampere, N. J.
Monahan, H. W., Fort William, Ont.
Petrowsky, J. F., Ampere, N. J.
Poesl, C. N., Buffalo, N. Y.
Ralston, S. A., Rockford, Ill.
Randall, H. E., Jr., Montreal, Que.
Reding, J. J., Cedar Rapids, Ia.
Redmund, F., Chicago, Ill.
Ross. E. E., Pittsburgh, Pa.
Rugg, H. H., Lead, S. D.
Ryan, J. A., New York, N. Y.
Sabanieff, A. A., Maynard, Mass.
Sanford, G. B., Rio Vista, Cal.
Smith, A., Buenos Aires, Arg. Rep.
Smith, A. H., New York, N. Y.
Snow, C. J., St. Paul, Minn.
Snyder, C. E., Pittsburgh, Pa.
Staehle, P. M., Ft. Wayne, Ind.
Streuber, R. G., New York, N. Y.
Strieby, W. J., Philadelphia, Pa.
Sydow, W., Denver, Colo.
Taylor, G. R. (Member), Medicine Hat, Alta.
Tolhurst, W. H., Casper, Wyo.
Treat, R., Schenectady, N. Y.
Ulrich, A. E., Chicago, Ill.
Van Alst, J. W., Philadelphia, Pa.
Van De Water, L., Pittsfield, Mass.
Van Steenberg, C.F., Pedro Miguel, C. Z.
Wallace, J. K., Cleveland, O.
Wilson, G. F., Los Angeles, Cal.
Wood, H. G., New York, N. Y.
Wright, B. S., Cedar Rapids, Ia.
Total 106

STUDENTS ENROLLED APRIL 13, 1917

8913 Church, L., Univ. of Illinois.
8914 Heckler, L. C., Univ. of Ill.
8915 Schroeppel, H. H., Univ. of Ill.
8916 Foster, T. L., Univ. of Penna.
8917 Powell, R. A., Wentworth Inst.
8918 Pfeiffer, C. L., Univ. of Ill.
8919 Hancock, S., Univ. of Ill.
8920 Burgess, W.B., Worcester Poly. Inst.
8921 Robinson, R. W., Univ. of Penna.
8922 Yang, T. S., Univ. of Ill.
8923 Callahan, G.E., Highland Park Coll.
8924 Kondo, J. S., Seattle Engg. Sch.
8925 Kiso, D., Univ. of Washington.
8926 Wagner, C.F., Carnegie Inst. Tech.
8927 Kurz, L. D., Univ. of Wis.
8928 Azar, T. P., Drexel Institute.
8929 Serfass, D. L., Penna. State Coll.
8930 Salsbury, R.J., Carnegie Inst. Tech.
8931 Miller, W.C., Carnegie Inst. Tech.
8932 Gibbon, W. R., Cornell Univ.
8933 Barr, S. M., Cornell Univ.
8934 O'Brien, B. P., Yale Univ
8935 Ward, W. E., Ohio Nor. Univ.
8936 Ocker, E. J., Casino Tech. Night School.
8937 Berry, H. M., Univ. of Penna.
8938 Scott, A. F. H., Univ. of Wis.
8939 Gray, H. F., Wentworth Inst.
8940 Gray, C., Penna. State Coll.
8941 Riddle, D.D., Colo. School of Mines.
8942 Tessohn, I. M., Columbia Univ.
8943 Palmisan, F. F., Pratt Inst.
8944 Foster, J., Carnegie Inst. Tech.
8945 Glasgow, R. S., Washington Univ.
8946 Fattmann, A.A., Washington Univ.
8947 Edquist, P. E., Univ. of Wash.

Digitized by Google

8948 Shapiro, E., Newark Technical Sch.
8949 Burk, H. G., Mass., Inst. Tech.
8950 Behringer, C. R., Utica Free Academy.
8951 Balch, C. F., Univ. of Wis.
8952 Young, F. C., Univ. of Wash.
8953 Piper, P. R., Howard Univ.
8954 Gartland, H. F., Univ. of Penna.
8955 Chavannes, A. L., Univ. of Tenn.
8956 Utley, R. L., Univ. of Cincinnati
8957 Guihan, W. C., Pratt Inst.
8958 Finnemore, H. F., Queen's Univ.
8959 Stelle, J. G., N. Y. Elec. Sch.
8960 Stout, M. B., Univ. of Pittsburgh.
8961 Copp, C. R., Univ. of Kansas.
8962 Huettner, G. R., Univ. of Wash.
8963 Streiff, A., Ore. Agri. Coll.
8964 Mejia, J. E., Rensselaer Poly Inst.
8965 Lipps, W. L., Lafayette Coll.
8966 Harvey, W. R., Univ. of Mich.
8967 Hyde, M. W., Univ. of Mich.
8968 Kilmer, J. J., Univ. of Mich.
8969 Lean, W. A., Univ. of Mich.
8970 Marsteller, F. G., Univ. of Mich.
8971 Porter, W. L., Univ. of Mich.
8972 Myers, C. F., Univ. of Mich.
8973 Brodhead, W., Univ. of Mich.
8974 Fairman, J. F., Univ. of Mich.
8975 Featherstone, E.B., Univ. of Mich.
8976 Hagen, E. F., Univ. of Mich.
8977 Daubert, H. C., N. Y. Elec. Sch.
8978 Shaw, H. N., Univ. of Wis.
8979 Kendall, H. C., Queen's Univ.
8980 Andrews, F. P., Stanford Univ.
8981 Anderson, E. S., Stanford Univ.
8982 Suydam, C. H., Stanford Univ.
8983 Storm, H. O., Stanford Univ.
8984 Bushnell, S. W., Univ. of Wash.
8985 Grimshawe, J. L., Carnegie Inst. Tech.
8986 Roberts, W. van B., Princeton Univ.
8987 Pearson, O.E., Carnegie Inst. Tech.
8988 Bartholomew, J. H., Wentworth Inst.
8989 Rockett, F. H., Mass. Inst. Tech.
8990 Neuman, Robert, Jr., Univ. of Colo.
8991 Farrier, R. A., Wash. State Coll.

Total 79.

OBITUARY

JOSEPH P. DAVIS, electrical engineer, formerly chief engineer of the American Telephone and Telegraph Company, died March 31 at his home 332 Palisade Ave., Yonkers, in his eightieth year. He was born at Northboro, Mass., and was educated at Rensselaer Polytechnic Institute. He served as assistant engineer of the Brooklyn Water Works and as chief engineer of the Brooklyn Park Department. The St. Louis Water Works and the Lowell (Mass.) Water Works also were constructed under his supervision. Mr. Davis was one of the charter members of the A. I. E. E. and a member of many other engineering societies.

PERSONAL

MR. D. W. BLAKESLEE, assistant superintendent of the Penn Electrical and Mfg. Co., Irwin, Pa., has received his commission of First Lieutenant in the Engineer Section of the Officers' Reserve Corps. Mr. Blakeslee has been connected with the Westinghouse Electric and Mfg. Co., the Duquesne Light Co., and was at one time assistant professor of electrical engineering in the University of Arkansas. He is a member of the A. I. E. E., the I. E. S., the N. E. L. A., the S. P. E. E., and the American Association for the Advancement of Science.

DR. W. F. M. Goss has been elected President of the Railway Car Manufacturers' Association and entered upon the duties as an officer in that association on March 1. Dr. Goss has since 1907 been Dean of the College of Engineering of the University of Illinois. His office will be located temporarily at 1120 Frick Bldg., Pittsburgh, Pa.

PROF. ROBERT L. ROCKWELL, head of the Department of Electrical Engineering of the Seattle Engineering School for the past five years, has resigned his position and formed a partnership with

Digitized by Google

Mr. Henry R. Stevens. They are now conducting a consulting electrical and mechanical engineering business at 955 Empire Bldg., Seattle, under the firm name of Stevens and Rockwell, Consulting Engineers.

ACCESSIONS TO LIBRARY

This list includes books which have been presented to the library of the A. I. E. E. and the U. E. S. during the past month, not including periodicals and other exchanges.

American Institute of Electrical Engineers. Handbook, 1900. (Gift of Chas. L. Clarke.)

Franco-American Trade. Report to the American Manufacturers Export Association by the American Industrial Commission to France. September-October, 1916. (Gift of American Manufacturers Association.)

Kennelly Reprints, vol. 8, 1915-16. (Gift of A. E. Kennelly.)

"Mechanical World" Electrical Pocket Book for 1917. Manchester, Eng., 1917. (Gift of Norman, Remington Co.)

Motor Bus Relief for New York's Transit needs. (Gift of the Fifth Ave. Coach Company.)

Sul funzionamento dei tubi a vuoto a tre elettrodi (audion), usati nella radiotelegrafia. By G. Vallauri. Milano, 1917. (Gift of Istituto Elettrotecnico e Radiotelegrafico della R. Marina.)

Western Union Telegraph Company. Annual Report 1916. New York, 1917. (Gift of Company.)

UNITED ENGINEERING SOCIETY

Above the Clouds and Old New York. An historical sketch of the site and a description of the many wonders of the Woolworth Building. By H. A. Bruce. New York, n.d. (Gift of Alice J. Gates.)

American Institute of Consulting Engineers, Inc. List of Members 1915, 1916. New York, 1915, 1916. (Gift of American Institute of Consulting Engineers.)

California. State Oil and Gas Supervisor. Annual Report 1st (Bulletin No. 73, California State Mining Bureau.)

Chemical and Biological Survey of the Waters of Illinois. (Univ. of Illinois. Water Survey Series No. 13.) Urbana, 1916. (Gift of University of Illinois.)

Coast Artillery School Annual Report of the Commandant, 1916. Fort Monroe, Va. 1917. (Gift of School.)

Compulsory Health Insurance, some vital facts and considerations in respect to March, 1917. By M. W. Alexander. (Gift of author.)

Congrés de la Houille Blanche. Compte Rendu. 1902, vols. 1-2; 1914, vols. 1-2. Grenoble, 1902, 1914. (Gift of Clemens Herschel.)

Electrical Patents (May-June 1916). (Gift of Mitchell and Allen.)

Hawkins Electrical Guide. Questions, answers and illustrations, Nos. 7, 8, 9. New York, 1914-15. (Gift of Theo. Audel & Company.)

How a Twenty Million Dollar Railroad was Built in Mid-Air. Third Tracking the New York "L." New York, Interborough Rapid Transit Co., n.d. (Gift of Theodore P. Shonts.)

How Does Industrial Valuation Differ from Public Utility Valuation. By John H. Gray. (Presented at the Annual Meeting, of Amer. Soc. Mechanical Engrs. Dec. 1916). (Gift of Clemens Herschel.)

Moline, Ill. Annual Report of the City Civil Engineer. 1915. (Gift of City Council.)

Mount Vernon, N. Y. Comptroller's Office. Annual Report. 21st, 1916. Mount Vernon, 1916. (Gift of Comptroller's Office.)

National Advisory Committee for Aeronautics. Annual Report. Second, 1916. Washington, 1917. (Gift of Committee.)

New Jersey. Board of Public Utility Commissioners. Uniform System of Accounts for Electric Light, Heat and Power Utilities, Trenton, 1914.

——for Gas Utilities. Trenton, 1914.

——for Water Utilities. Trenton, 1912. (Gift of Chas. H. Armstrong.)

New York City. Hall of Records Power Plant. Report and Discussion of Physical test and costs of operation and maintenance, test conducted in 1913, under the auspices of a Board of Engineers composed of representatives of the City of New York, The New York Edison Company and the New York Bureau of Municipal Research. New York, 1916. (Gift of Municipal Reference Library.)

New York State Library. Annual Report 98, 1915. Albany, 1917. (Gift of University of the State of New York.)

Newark, Ohio, City Auditor. Annual Report of the City Auditor of City. 1916. Newark, 1916. (Gift of Newark Auditing Dept.)

Niagara Falls, N. Y. City Council. Financial Report of the City Clerk, 1916.

——Recommendations of the City Manager, 1917. (Gift of City Council.)

Penalties and Liquidated Damages. By W. B. King. (Reprinted from Architectural Forum, Feb. 1917.) (Gift of King & King.)

Public Service Properties, 1914, 1915. New York, W. S. Barstow & Co., 1914-15. (Gift of Chas. H. Armstrong.)

Skin effect resistance measurements, conductors at radio-frequencies up to 100,000 cycles per second. By A. E. Kennelly and H. A. Affel. (Bulletin No. 13, Massachusetts Institute of Technology, Electrical Engineering Dept. Dec. 1916.) (Gift of Massachusetts Institute of Technology.)

Specifications for Fire Hose and Report Thereon, January, 1917. Rochester Bureau of Municipal Research, Inc. Rochester, N. Y. (Gift of Jas. W. Routh.)

Syracuse University. Structure of the common woods of New York and the wood collection.

Digitized by Google

(Bulletin of N. Y. State College of Forestry, vol. 15, No. 3, March ,1915.)

——Wood using industries of New York. (N. Y. State College of Forestry, Ser. XIV, No. 2.)

——The New York State Ranger School on the College Forest at Wanakena, N. Y. (Circular No. 14, N. Y. State College of Forestry.)

——List of Publications of the N. Y. State College of Forestry. (Circular No. 16). (Gift of Syracuse University.)

The John Fritz Medal. New York, 1917. (Gift of John Fritz Medal Board.)

Two Opposing Railroad Valuations. (Reprinted from the Unpopular Review, Jan-March 1917.) (Gift of Clemens Herschel.)

Uniform System of Accounts for Electric Railways, prescribed by the Interstate Commerce Commission in accordance with section 20 of the Act to Regulate Commerce. Washington, 1914. (Gift of Chas. H. Armstrong.)

University of Illinois. Brief prepared for the Governor and the General Assembly of the State concerning the work of the College of Engineering and the Engineering Experiment Station and a statement of their needs for the two years beginning July 1, 1917. Urbana, 1917. (Gift of University.)

Vermont Public Service Commission. Biennial Report 15th, 1916. Brattleboro, 1916. (Gift of Public Service Commission.)

Volamekum. Handbuch für Luftfahrer. By Ansbert Vorreiter and Hans Boykow. Munchen, 1912. (Gift of Leon Cammen.)

Wichita, Kansas. Financial Statement of City for 1911-1916. (Gift of City Council.)

Wilkes-Barre, Penn. Superintendent of Department of Accounts & Finance. Annual Report. 2d, 1915.

——Proceedings of the 17th Annual Convention of the League of Cities of the Third Class in Pennsylvania held at Johnstown, Aug. 29-31, 1916. (Gift of Wilkes-Barre City Clerk).

Wilmington, Del. Water Commissioner. Annual Report. 46th, 1914-15.

——Chief of Police. Report 1916.

——Park Commissioners. Report of the Board, 1915.

——Street & Sewer Department. Annual Statement of the Board of Directors. 1916. (Gift of Water Commissioners.)

Wilmington, N. C. Report of Audit for year ending May 31, 1916. Wilmington, N. C. 1916. (Gift of City Council.)

EMPLOYMENT BULLETIN

Vacancies.—The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN. The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-208. Young technical men are wanted by large operating company near New York City for field and drafting work relative to engineering records and circuit designs. Give experience and qualifications.

V-216. Good opportunity for young technical graduate with some selling experience, for sales position with company manufacturing specialized apparatus, located in Greater New York. Please give full details regarding experience, and salary desired.

V-233. Wanted: Recent engineering graduate to take up economy studies in pole line and cable plant construction. Man having some experience in estimating the cost of such construction given preference. State experience and salary desired.

V-234. Corporation manufacturing electrical machinery, generators, regulators, etc., requires immediately the services of an assistant purchasing agent. Several years' previous experience in this work necessary. In reply, state age, salary expected, whether married, present occupation, etc. This is a real opportunity for the right man.

V-235. Large chemical manufacturing company requires the services of several draftsmen experienced in the design of chemical plants or machinery.

Digitized by Google

Salaries $30 to $50 per week, depending upon experience and ability. Please give full particulars.

V-238. Old established, rapidly growing concern, can find room for few college graduates with at least one year's experience in transformer testing or design. Those who prove their value and outgrow the initial position will be rapidly promoted. This is a real opportunity and to be considered applicants should state details of past experience and salary wanted in first letter. Location near Boston.

V-239. Assistant to chief engineer, as an understudy, wanted by Eastern corporation manufacturing machinery involving application of a transformer. Applicants must be well versed in design of standard machine tools like milling machines, shapers, etc.; should also have a fair knowledge of transformer design. An unusual opportunity is offered to the right man to connect with a progressive concern. We are willing to pay $2500 to $3000 for the right man, but will not accept ambition in place of experience. State full past experience in first letter to receive consideration.

V-240. Wanted: Graduate engineer with experience in power house and substation design and construction. Position in engineering office in city on the Atlantic Coast. State full particulars of education and experience, and salary expected.

MEN AVAILABLE

734. Engineer, age 33, married. Graduate B.M. and E.E. Two years operating, two and a half years G.E. test, four years charge construction work, installing steam turbines, generators, motors and switchboards. Employed; reason for change desires permanent location with chance for advancement. Salary $1800.

735. Teacher of Electrical Engineering, with degree of E.E. and M.E.E., three years' college teaching experience and some practical experience. Has taught both a-c. and d-c. theory and laboratory, telephony, and short courses; some corporation school experience. Age 34, single. Desires position in New England or Southern college. Salary moderate if other conditions are satisfactory. Available September 1.

736. Relay and Meter Expert. Eight years' practise. Capable of calculating short-circuit values and relay settings; familiar with oscillograph work and various kinds of power house and substation testings. Wishes position in testing department; willing to take charge of relay and meter work. No travelling. Married. Technical education.

737. Electrical technical graduate, with nine years' practical experience in electrical power generation, distribution, construction, operation and design. At present in charge of industrial plant. Desires chance for advancement. Salary $1800.

738. You are searching for experienced technical men with business and executive abilities. I have these qualifications; am also technical graduate with ten years' experience both as an engineer and operating manager of public utility business, particularly electric light and power properties, steam and hydraulic driven. Some gas and water experience. Let me write you further.

739. Assoc. A. I. E. E., age 24, technical education; four years' practical experience, mostly power plant and substation installations, storage batteries, experimental work on electric furnaces, operating a-c. and d-c. Diesel engine plant, etc. Desires position with mining or power company. Prefers West but will go anywhere. Some slight knowledge of Spanish.

740. Electrical Engineer with degree from college of recognized standing wishes to locate with small manufacturing or sales company in the capacity of construction or sales engineer. Has had considerable practical experience with power installations. Was employed in the engineering departments of large public utility company. Age 25; single, will go anywhere in the States.

741. Brazilian Electrical Engineer, expert translator, experienced Portuguese correspondent, speaking also English, French, Italian and Spanish, rapid typist, export and import experience, desires position. Manufacturing concern interested in South American trade preferred. Willing to travel. First-class connections in Brazil.

742. Graduate Electrical Engineer, age 25, with post-graduate work in large Eastern University, available July 1. Two years' teaching and research in high-voltage engineering. Desires position as assistant engineer with central station or manufacturing concern where promotion comes by ability and hard work. Strictly temperate.

Digitized by Google

743. Instructor in Electrical Engineering. Degree of B.S. with thesis well under way for E.E. Three years of practical experience and two years in teaching. Present engagement three hours theory and five hours laboratory and shop. Desires broader opportunity after July.

744. Electrical Engineer, technical education and fifteen years' experience in responsible charge electrical departments large industrial, mining and smelting plants. Accustomed to handling men successfully as well as engineering problems both operating and construction. Mem. A. I. E. E.

745. Superintendent, ten years in the central field, desires change. Technical graduate, followed up by shop experience. At present and for the past six years at the head of central station, more than doubling its income in that time. Has had experience in all branches of the work, including high-tension transmission and industrial power applications.

746. Associate; American; thirty; temperate. Recently in charge power department large mining company operating private hydroelectric plant, high-tension transmission and distribution, haulage, etc., where continuity of service was a requisite. Reason for leaving, no future. Available immediately; New York interview; speak Spanish; go anywhere. Least salary $2400.

747. Electrical Engineer, technical graduate, seven years with the General Electric Co., testing department, instrument laboratory, transformer design, and three years as construction foreman in the United States, Canada, and Cuba; will be available June 15.

748. Engineer, age 35, married, Mem. A. I. E. E., Assoc. Mem. A. S. M. E., sixteen years' experience in design, manufacture and application of small and moderate size a-c. and d-c. motors and generators, desires position as designer or factory superintendent. At present employed. Available June 1.

749. Electromechanical Engineer, graduate, age 31, married; nine years' varied experience in testing, drafting and design of a-c. and d-c. machinery for industrial work; designer of signalizing apparatus for submarines; has held position of chief draftsman with wireless telegraph company; perfectly familiar with advanced theory of electrical engineering, physics and mathematics. Speaks five languages.

750. Graduate Electrical Engineer, thoroughly experienced in industrial power applications and the planning, construction and operation of industrial power systems, desires position as chief electrician of large industrial concern or as industrial power engineer with central station company. Now employed with big steel company. Twelve years' experience. Highly recommended.

751. Technical graduate, with executive ability and five years' practical experience in the design, construction, and operation of electric power stations, transmission systems and distribution systems; desires position as manager of electric light company. Has made good in present work and desires something larger. Age 32; married; in good health. Available on thirty days' notice.

752. Electrical Engineer, interested in industrial research and development work along electrical engineering, electrophysical or electrochemical lines. M. S. E. E. and A. B.; nearly four years' experience and in charge of research. Will be glad to submit full particulars as to character and ability, and will only undertake, as in the past, work which he is confident to bring to successful issue.

753. Assoc. A. I. E. E., technical education, experience motor repair and appliances. At present engaged in maintaining electrical plant. Desires to make change for concern that is constructing or maintaining electrical plant in U. S. with a future in view. Age 22. Salary $25.00.

754. Electrical Engineer, 33, married, desires position as manager of electrical repair company, testing engineer in manufacturing company, or as electrical assistant to operating engineer in a large power company. Have fifteen years' experience. Illinois preferred. Salary $1800.

755. Responsible position, with central station or industrial plant, wanted by graduate engineer familiar with the operation, maintenance and installation of modern power plant and substation machinery, the erection and maintenance of transmission lines, the operation of refrigeration machinery, etc. Ten years' experience. At present employed.

756. Electrical Engineer, technical graduate (1913), and graduate physicist (1908), with G.E. test floor experience, now employed in teaching physics and electrical engineering at $1700; desires position in commercial work where laboratory and technical training would

Digitized by Google

be of value. Would accept some reduction in salary if prospects are good.

757. Electrical Engineer, with ten years' general engineering experience, followed by fifteen years' work construction, operation and maintenance of hydroelectric plants. At present superintendent of large hydroelectric station in the East; will consider change if good business inducements are given. Minimum salary considered East or South, $4000; middle West or Pacific Coast, $5000.

758. Do you desire the services of a man who has had an experience of twenty-four years in the construction and operation of electric railway and lighting properties, especially the former? Have specialized in power and substation work. Will go anywhere. Available after May 15.

759. Electrical Engineer, twelve years' experience, three in Europe and nine years for American firm, desires to be representative for Italy for American electrical concern. English, French, German, Italian and Spanish languages well known.

760. Electrical and Mechanical Engineer, 31, technical graduate; at present works engineer in one of the largest manufacturing plants in the country. Have had considerable practical shop experience. Would accept position as superintendent or works engineer. Salary expected—$3000 per year. Married.

761. Electrical Engineer, Russian, age 30. Seven years' experience selling, operating, developing, testing and installing all kinds of electrical machinery Speaks Russian, German, French and English. Wishes position with American firm desirous of developing trade with Russia, in which country he has excellent connections.

762. Young Electrical Engineer of India, graduate of an American university, with eight years' experience in America, England and India, in the operation and testing of central station machinery, desires position with some hydroelectric or manufacturing company in any capacity, preferably in testing work. Author of a laboratory book. Mem. A. I. E. E.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917)
GEORGE A. HAMILTON

SECRETARY.
F. L. HUTCHINSON

HONORARY SECRETARY.
RALPH W. POPE

LIBRARIAN.
W. P. CUTTER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to May 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.

N. A. Carle,	George A. Hamilton,
John H. Finney,	William McClellan,
Bancroft Gherardi,	J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.

N. A. Carle,	Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.

Frederick Bedell,	F. W. Peek, Jr.
Philander Betts,	F. L. Rhodes,
H. H. Clark,	D. W. Roper,
J. G. De Remer,	Harris J. Ryan,
H. A. Hornor,	T. H. Schoepf
Edward P. Hyde,	Charles P. Steinmetz,
L. E. Imlay,	N. W. Storer,
E. H. Martindale,	Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.

Frederick Bedell,	L. T. Robinson,
M. G. Lloyd,	C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.

J. C. Forsyth,	H. R. Sargent,
H. B. Gear,	G. A. Sawin,
A. H. Griswold,	A. M. Schoen,
H. O. Lacount,	George F. Sever,
Johnston Livingston,	C. E. Skinner,
Henry N. Muller	H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 W. 23rd Street, New York.

E. B. Katte,	W. I. Slichter,
F. L. Rhodes,	Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.

J. G. De Remer,	A. M. Schoen,
Paul M. Lincoln,	J. H. Tracy,

and the chairmen of all Institute Sections, *ex-officio.*

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.

G. M. Baker,	W. G. Chace,
S. H. Blake,	H. W. Flashman,

E. H. Martindale,
and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.

E. A. Carolan,	A. M. Hunt,
John J. Carty,	William McClellan,
Fredk. Darlington,	H. H. Porter,
Gano Dunn,	C. S. Ruffner,
John B. Fisken,	A. M. Schoen,

L. B. Stillwell,

COMMITTEE ON DEVELOPMENT OF WATER POWER

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.

F. O. Blackwell,	Nicholas S. Hill, Jr.,
Francis Blossom,	E. A. Lof,
Gano Dunn,	W. V. N. Powelson,

L. B. Stillwell.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.

P. G. Agnew,	H. M. Hobart,
Frederick Bedell,	H. D. James,
Joseph Bijur,	P. Junkersfeld,
L. F. Blume,	A. E. Kennelly,
James Burke,	G. L. Knight,
G. A. Burnham,	A. S. McAllister,
N. A. Carle,	W. M. McConahey,
E. J. Cheney,	W. L. Merrill,
H. H. Clark,	Charles Robbins,
E. H. Colpitts,	L. T. Robinson,
F. P. Cox,	C. H. Sharp,
W. A. Del Mar,	C. E. Skinner,
E. J. Edwards,	A. J. Slade,
H. W. Fisher,	N. W. Storer,
W. S. Gorsuch,	R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.

C. A. Adams,	M. I. Pupin,
B. A. Behrend,	E. B. Rosa,
Louis Bell,	Charles F. Scott,
James Burke,	Clayton H. Sharp,
John J. Carty,	Samuel Sheldon,
Gano Dunn,	C. E. Skinner,
H. M. Hobart,	Charles P. Steinmetz,
John W. Lieb,	Elihu Thomson,
R. B. Owens,	Philip Torchio.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.

Bion J. Arnold,	Charles A. Terry,
John F. Kelly,	B. F. Wood,

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.
A. E. Kennelly, Chairman, Robert T. Lozier, S. G. McMeen.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler, J. Franklin Stevens.

Term expires July 31, 1919.
Charles F. Brush, N. W. Storer, C. C. Chesney.

Term expires July 31, 1920.
Carl Hering, Harris J. Ryan.

Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi, E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.
B. A. Behrend, Paul M. Lincoln, William McClellan.

Term expires July 31, 1918.
C. A. Adams, Harold Pender, C. E. Skinner.

Ex-Officio.
H. W. Buck, President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to May 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
55 Liberty Street, New York.

J. M. Drabelle,
C. C. Egbert,
W. S. Gorsuch,
John Harisberger,
A. H. Kruesi,
Paul M. Lincoln,
Wynn Meredith,
I. E. Moultrop,
S. A. Moss,
R. J. S. Pigott,
Cecil Poole,
E. F. Scattergood,
F. A. Scheffler,
W. R. Thompson,
Philip Torchio,
H. L. Wallau,
B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,
M. T. Crawford,
E. E. F. Creighton,
H. H. Dewey,
P. M. Downing,
H. W. Fisher,
F. A. Gaby,
W. T. Goddard,
O. A. Havill,
R. F. Hayward,
J. P. Jollyman,
P. M. Lincoln,
W. E. Mitchell,
G. J. Newton,
L. C. Nicholson,
W. D. Peaslee,
Stefaan Piek,
C. S. Ruffner,
H. J. Ryan,
F. D. Sampson,
H. E. Shedd,
Julian C. Smith,
P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman.
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,
A. H. Babcock,
Reinier Beeuwkes,
E. J. Blair,
L. P. Crecelius,
J. V. B. Duer,
George Gibbs,
W. J. Harvie,
Hugh Hazelton,
E. B. Katte,
P. J. Kearny,
William McClellan,
John Murphy,
W. B. Potter,
E. D. Priest,
Charles H. Quinn,
Clarence Renshaw,
A. S. Richey,
Charles F. Scott,
John B. Taylor,
H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,
J. H. Davis,
James Dixon,
A. M. Dudley,
Herbert D. Dwight,
F. W. Ells,
J. E. Fries,
F. R. Fishback,
R. H. Goodwillie,
A. L. Hadley,
G. A. Johnstone,
C. A. Kelsey,
C. L. Kennedy,
Charles D. Knight,
A. H. Lawton,
A. M. MacCutcheon,
A. G. Pierce,
James M. Smith,
H. Weichsel,
J. B. Wiard,
R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,
C. E. Clewell,
J. R. Cravath,
T. S. Perkins,
Richard C. Powell,
E. B. Rosa,
W. D'A. Ryan,
Clayton H. Sharp,
W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,
W. H. Blood, Jr.
Fred A. Bryan,
C. L. Cory,
Harry Clifford Eddy,
W. B. Jackson,
A. H. Kruesi,
William McClellan,
Norman C. McPherson,
Allard Smith,
W. G. Vincent,
George W. Wittemore,
Clifton. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
72 W. Adams St., Chicago, Ill .

L. L. Elden,
G. Faccioli,
V. E. Goodwin,
E. M. Hewlett,
Paul M. Lincoln,
A. A. Meyer,
L. C. Nicholson,
N. L. Pollard,
S. D. Sprong,
Philip Torchio,
H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,
F. A. J. Fitzgerald,
A. F. Ganz,
F. A. Lidbury,
F. G. Liljenroth,
Eugene F. Roeber,
J. A. Seede,
R. Tencher.

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,
A. C. Crehore,
G. Faccioli,
C. L. Fortescue,
W. S. Franklin,
A. E. Kennelly,
E. B. Rosa,
Harris J. Ryan,
Clayton H. Sharp,
C. P. Steinmetz,
P. H. Thomas,
J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
195 Broadway, New York.

E. F. W. Alexanderson,
R. E. Chetwood,
M. M. Davis,
C. L. Fortescue,
H. M. Friendly,
F. B. Jewett,
S. M. Kintner,
Wm. Maver, Jr.,
Kempster B. Miller,
H. Mouradian,
W. O. Pennell,
Allard Smith,
John S. Stone,
John B. Taylor,
J. L. Wayne, 3rd.
G. M. Yorke.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.

D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,
M. W. Day,
G. E. Edgar,
W. L. R. Emmet,
W. R. Furlong,
H. L. Hibbard,
Guy Hill,
O. P. Loomis,
G. A. Pierce, Jr.,
H. M. Southgate,
E. A. Sperry,
Wilfred Sykes,
F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,
Frank H. Armstrong,
Graham Bright,
W. A. Chandler,
F. J. Duffy,
L. C. Ilsley,
R. L. Kingsland,
Charles Legrand,
Charles M. Means,
K. A. Pauly,
H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,
F. B. Crosby,
E. Friedlaender,
E. S. Jeffries,
D. M. Petty,
A. G. Pierce,
J. C. Reed,
R. Tencher,
Brent Wiley,
R. B. Williamson
J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.

Alexander Gray,
E. J. Henkhe,
E. A. Loew,
William McClellan,
Chester W. Rice,
C. E. Skinner
R. D. Thomson,

Digitized by Google

SPECIAL COMMITTEES.

Revised to May 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
F. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman,
Massachusetts Institute of Technology, Boston, Mass.
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. F. Scott.

COMMITTEE ON NATIONAL DEFENSE

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.

F. C. Bates, Secretary,
30 Church Street, New York,

B. J. Arnold, D. C. Jackson,
A. H. Babcock, John W. Lieb,
Philander Betts, P. M. Lincoln,
H. W. Buck, Ralph D. Mershon,
J. H. Cuntz, A. M. Schoen,
J.J. Carty J. Franklin Stevens.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S. McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

Ralph D. Mershon, Paul M. Lincoln,
C. O. Mailloux, John J. Carty.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Harold Pender, Edward D. Adams,
W. I. Slichter, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan,
John J. Carty.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles P. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand,
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.
A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France.
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa.

ENGINEERING COMMITTEE OF THE ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE

H. W. Buck, C. A. Adams.

Digitized by Google

LIST OF SECTIONS

Revised to May 1, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg.Atlanta,Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St., Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, 433 West Forest Ave., Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Union Tel. Co. Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	Gordon Campbell	M. B. Carroll, G. E. Co., West Lynn, Mass
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7. '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, 1220 Spalding Bldg., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	J. W. Morrison, Rochester Telephone Co., Rochester N. Y.
St. Louis.....Jan. 14, '03	A.McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	E. T. J. Brandon	Wills Maclachlan, 910 Excelsior Life Building, Toronto, Ont.
Urbana.....Nov. 25, '02	I. W. Fisk	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.....June 25, '14	D. Nankervis	L. J. Corbett, Univ. of Idaho, Moscow, Idaho.
Iowa State College....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col..Jan. 10, '08	R. H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	N. M. Foster	G. M. Bowman, 1517 New Hampshire, Lawrence, Kansas.
Kentucky, State Univ. ofOct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Samuel McC. Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech.....Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of...May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr., and Mech. Arts.Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of.Feb. 15, '17		
Norwich University....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University..Dec. 20, '02	H. D. Bender	L. W. Birch, 138 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of....Oct. 11, '12	H. M. Richards	R. E. Heffner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly,	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst..Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of...Dec. 13, '07	D. M. Alexander	C. W. Cutler, 702 California St., Pullman, Wash.
Washington Univ.....Feb. 6, '04	Charles A. Lieber	R. W. MacDonald, Washington University, St. Louis, Mo.
Washington, Univ. of..Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst...Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 59

Digitized by Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI JUNE, 1917 Number 6

SPECIAL MEETING OF A. I. E. E. NEW YORK, JUNE 27-28, 1917

At its last meeting, the Board of Directors of the Institute voted to hold a special Institute meeting in New York, June 27-28, 1917, for the presentation and discussion of papers that were to be presented at the Annual Convention.

The Meetings and Papers Committee has arranged for five technical sessions which will be held morning and afternoon of each day and on Wednesday evening. The monthly meeting of the Board of Directors will be held Wednesday afternoon at 4:30 o'clock. The program is as follows;

First Session
Wednesday, June 27,
10:30 A.M.

Subject: High-Tension Cables

Problems in Operation and Maintenance of Underground Cables, by John L. Harper.

High-Tension Cable Joints, by D. W. Roper.

The Influence of Dielectric Losses on the Rating of High-Tension Underground Cables, by A. F. Bang and H. C. Louis.

Insulation Characteristics of High-Voltage Cables, by W. S. Clark and G. B. Shanklin.

Second Session
Wednesday, June 27,
2:00 P.M.

Subject: High-Tension Insulators

The Insulator Situation, By W. D. Peaslee.

Expansion Effects as a Cause of Deterioration in Suspension Type Insulators, by J. A. Brundige.

Present Practise in Design and Manufacture of High-Tension Insulators, by A. O. Austin.

Wednesday, June 27,
4:30 P.M.

Monthly meeting of the Board of Directors.

Third Session
Wednesday, June 27,
8:30 P.M.

President's Annual Address.

Introduction of President-Elect E. W. Rice, Jr.

Reports of Technical Committees.

Fourth Session
Thursday, June 28,
10-30 A.M.

Subject: Mining

Forms of Power Best Suited for Various Loads Encountered in the Operation of Bituminous Coal Mines, by R. L. Kingsland.

Test of a Large Mine Hoist, by R. S. Sage.

Fifth Session
Thursday, June 28,
2:00 P.M.

Subjects: Water Power, and Heating of Electrical Machinery

Economical Combination of Water Power and Steam Plants and a Convenient Method of Solution, by H. S. Putnam.

Digitized by Google

Cooling of Oil-Immersed Transformer Windings After Shut-Down, by V. M. Montsinger.

The latter paper was to have been presented at the Schenectady meeting which was canceled, and is published in the April PROCEEDINGS. The papers by Messrs. Harper, Peaslee, and Brundige were published in the May PROCEEDINGS, and the balance of the papers, with the exception of those for the Mining Session, appear in this issue. Reprints of all the papers and of the technical committee reports will be distributed at the meeting.

ANNUAL MEETING AND EDISON MEDAL PRESENTATION

The annual meeting of the A. I. E. E. was held at the Institute headquarters 33 West 39th Street, New York, on Friday, May 18th, at 8:30 p.m. The meeting was called to order by President Buck who called upon Secretary Hutchinson to present the Annual Report of the Board of Directors. This report which was distributed at the meeting was briefly abstracted by Secretary Hutchinson. The report is published in full elsewhere in this issue.

The next order of business was the reading of the Report of the Committee of Tellers upon the election of officers for the administrative year beginning August 1, 1917. This report which is published elsewhere in this issue was presented by Secretary Hutchinson, after which President Buck announced the following named gentlemen as duly elected officers and managers: President E. W. Rice, Jr., Schenectady, N. Y.; Vice-Presidents Frederick Bedell, Ithaca, N. Y., John H. Finney, Washington, D. C., A. S. McAllister, New York, N. Y.; Managers, Walter A. Hall, West Lynn, Mass., E. H. Martindale, Cleveland, Ohio, William A. Del Mar, New York, N. Y., Wilfred Sykes, Pittsburgh, Pa.; Treasurer, George A. Hamilton, Elizabeth, N. J.

The ceremony of the presentation of the Edison medal to Nikola Tesla for "early original work in polyphase and high-frequency electric currents" followed the business meeting. Dr. A. E. Kennelly as chairman of the Edison medal committee outlined the origin and purpose of this honor and gave a brief history of past awards.

Charles A. Terry whose subject was a presentation of historical facts regarding the Tesla patents and contributions to the arts, said in part: "Twenty-nine years ago this month there was presented before this Institute a paper of unusual import, entitled 'A New System of Alternate-Current Motors and Transformers'. The author, Nikola Tesla, was then only thirty-one years of age and had been for only four years a resident of this country. At the age of twenty-two he had completed his studies in engineering at the Polytechnic School in Grätz and also a course in the University of Prague. In 1883 he was at Strassbourg completing the lighting of a newly erected railway station. Shortly after finishing this undertaking he came to the United States.

"Throughout all these years his desire had been to find an opportunity to demonstrate the truth of a conviction which became fixed in his mind while studying at Grätz in 1878. The conviction was that it should be possible to create a rotating magnetic field without the use of commutators. By some fortunate process of reasoning he conceived while in Budapest in 1882 that by using two or more out-of-phase alternating currents respectively passing through geometrically displaced coils it would be possible to develop his long-sought progressively shifting magnetic field.

"In 1885 Tesla had the good fortune to interest men of means in a direct-current arc light he had devised, and subsequently a laboratory was equipped for him. In 1887 he was able to exhibit to his business associates motors having such progressively shifting fields without the use of commutators, as he had forseen nine years before. The

Digitized by Google

rapidity and wonderful way in which he surrounded the entire field of constant speed, synchronous, induction and split-phase motors is set forth in his paper of May 18 and in the numerous patents issued May 1, 1888 and succeeding years.

"Among the first to recognize the immense importance of Mr. Tesla's motors were Mr. Westinghouse and his advisers, T. B. Kerr, Mr. Byllesby, Mr. Shallenberger and Mr. Schmid, and Mr. Westinghouse secured an option which shortly resulted in the purchase of the patents."

Mr. Terry also enumerated Tesla's experimental work in connection with wireless transmission of power and the control of movements of torpedoes and boats, as well as his contributions in the field of the Roentgen ray, his various electrical inventions, and the bladeless steam turbine for which commercial success is hoped.

President Buck then introduced Mr. B. A. Behrend who said in part:

"It is twenty-nine years ago to the very day and hour that Nikola Tesla stood before this Institute and read a description of his great discovery of the generation and utilization of polyphase alternating currents. He left nothing to be done, his paper contained even the skeleton of the mathematical theory.

"Three years later in 1891, there was given the first great demonstration, by Swiss engineers, of the transmission of power at 30,000 volts from Lauffen to Frankfort by means of Mr. Tesla's system. This was followed by the development of the Cataract Construction Company."

President Buck called attention to the apparently almost insurmountable obstacles which confronted Mr. Tesla, thirty years ago, the very elementary state of electrical knowledge, and the firm belief by the majority of prominent engineers that direct current was the sole practical means of electric power transmission. Mr. Buck then presented the medal to Nikola Tesla, expressing the appreciation of the entire engineering profession in his accomplishments and with the great hope that he may continue to contribute to the profession in the future.

Mr. Tesla, in accepting the medal, expressed his heartiest thanks for the sympathy and sincere appreciation expressed by the award. He then gave an outline of his life from boyhood, describing many most interesting experiences in connection with his everyday life as well as in the progress of his profession.

REPORT OF COMMITTEE OF TELLERS ON ELECTION OF OFFICERS

To the President,
American Institute of Electrical Engineers.

DEAR SIR:—This committee has carefully canvassed the ballots cast for officers for the year 1917-1918. The result is as follows:

Total number of ballot envelopes received	2675
Rejected on account of bearing no identifying name on outer envelope, according to Art. VI, Sec. 34 of the Constitution	33
Rejected on account of voter being in arrears for dues on May 1, 1917, as provided in the Constitution and by-laws	102
Rejected on account of having reached the Secretary's office after May 1, according to Art. VI, Sec. 34 of the Constitution	11
	146
Leaving as valid ballots	2529

These 2529 valid ballots were counted and the result is shown as follows:

For President

E. W. Rice, Jr.	2479
Scattering and blank	50

For Vice-Presidents

Frederick Bedell	2426
John H. Finney	2381
A. S. McAllister	2362
Scattering and blank	418

For Managers

Walter A. Hall	2454
E. H. Martindale	2449
William A. Del Mar	2446
Wilfred Sykes	2437
Scattering and blank	330

Digitized by Google

Cooling of Oil-Immersed Transformer Windings After Shut-Down, by V. M. Montsinger.

The latter paper was to have been presented at the Schenectady meeting which was canceled, and is published in the April PROCEEDINGS. The papers by Messrs. Harper, Peaslee, and Brundige were published in the May PROCEEDINGS, and the balance of the papers, with the exception of those for the Mining Session, appear in this issue. Reprints of all the papers and of the technical committee reports will be distributed at the meeting.

ANNUAL MEETING AND EDISON MEDAL PRESENTATION

The annual meeting of the A. I. E. E. was held at the Institute headquarters 33 West 39th Street, New York, on Friday, May 18th, at 8:30 p.m. The meeting was called to order by President Buck who called upon Secretary Hutchinson to present the Annual Report of the Board of Directors. This report which was distributed at the meeting was briefly abstracted by Secretary Hutchinson. The report is published in full elsewhere in this issue.

The next order of business was the reading of the Report of the Committee of Tellers upon the election of officers for the administrative year beginning August 1, 1917. This report which is published elsewhere in this issue was presented by Secretary Hutchinson, after which President Buck announced the following named gentlemen as duly elected officers and managers: President E. W. Rice, Jr., Schenectady, N. Y.; Vice-Presidents Frederick Bedell, Ithaca, N. Y., John H. Finney, Washington, D. C., A. S. McAllister, New York, N. Y.; Managers, Walter A. Hall, West Lynn, Mass., E. H. Martindale, Cleveland, Ohio, William A. Del Mar, New York, N. Y., Wilfred Sykes, Pittsburgh, Pa.; Treasurer, George A. Hamilton, Elizabeth, N. J.

The ceremony of the presentation of the Edison medal to Nikola Tesla for "early original work in polyphase and high-frequency electric currents" followed the business meeting. Dr. A. E. Kennelly as chairman of the Edison medal committee outlined the origin and purpose of this honor and gave a brief history of past awards.

Charles A. Terry whose subject was a presentation of historical facts regarding the Tesla patents and contributions to the arts, said in part: "Twenty-nine years ago this month there was presented before this Institute a paper of unusual import, entitled 'A New System of Alternate-Current Motors and Transformers'. The author, Nikola Tesla, was then only thirty-one years of age and had been for only four years a resident of this country. At the age of twenty-two he had completed his studies in engineering at the Polytechnic School in Grätz and also a course in the University of Prague. In 1883 he was at Strassbourg completing the lighting of a newly erected railway station. Shortly after finishing this undertaking he came to the United States.

"Throughout all these years his desire had been to find an opportunity to demonstrate the truth of a conviction which became fixed in his mind while studying at Grätz in 1878. The conviction was that it should be possible to create a rotating magnetic field without the use of commutators. By some fortunate process of reasoning he conceived while in Budapest in 1882 that by using two or more out-of-phase alternating currents respectively passing through geometrically displaced coils it would be possible to develop his long-sought progressively shifting magnetic field.

"In 1885 Tesla had the good fortune to interest men of means in a direct-current arc light he had devised, and subsequently a laboratory was equipped for him. In 1887 he was able to exhibit to his business associates motors having such progressively shifting fields without the use of commutators, as he had forseen nine years before. The

Digitized by Google

rapidity and wonderful way in which he surrounded the entire field of constant speed, synchronous, induction and split-phase motors is set forth in his paper of May 18 and in the numerous patents issued May 1, 1888 and succeeding years.

"Among the first to recognize the immense importance of Mr. Tesla's motors were Mr. Westinghouse and his advisers, T. B. Kerr, Mr. Byllesby, Mr. Shallenberger and Mr. Schmid, and Mr. Westinghouse secured an option which shortly resulted in the purchase of the patents."

Mr. Terry also enumerated Tesla's experimental work in connection with wireless transmission of power and the control of movements of torpedoes and boats, as well as his contributions in the field of the Roentgen ray, his various electrical inventions, and the bladeless steam turbine for which commercial success is hoped.

President Buck then introduced Mr. B. A. Behrend who said in part:

"It is twenty-nine years ago to the very day and hour that Nikola Tesla stood before this Institute and read a description of his great discovery of the generation and utilization of polyphase alternating currents. He left nothing to be done, his paper contained even the skeleton of the mathematical theory.

"Three years later in 1891, there was given the first great demonstration, by Swiss engineers, of the transmission of power at 30,000 volts from Lauffen to Frankfort by means of Mr. Tesla's system. This was followed by the development of the Cataract Construction Company."

President Buck called attention to the apparently almost insurmountable obstacles which confronted Mr. Tesla, thirty years ago, the very elementary state of electrical knowledge, and the firm belief by the majority of prominent engineers that direct current was the sole practical means of electric power transmission. Mr. Buck then presented the medal to Nikola Tesla, expressing the appreciation of the entire engineering profession in his accomplishments and with the great hope that he may continue to contribute to the profession in the future.

Mr. Tesla, in accepting the medal, expressed his heartiest thanks for the sympathy and sincere appreciation expressed by the award. He then gave an outline of his life from boyhood, describing many most interesting experiences in connection with his everyday life as well as in the progress of his profession.

REPORT OF COMMITTEE OF TELLERS ON ELECTION OF OFFICERS

To the President,
American Institute of Electrical Engineers.

DEAR SIR:—This committee has carefully canvassed the ballots cast for officers for the year 1917-1918. The result is as follows:

Total number of ballot envelopes received	2675
Rejected on account of bearing no identifying name on outer envelope, according to Art. VI, Sec. 34 of the Constitution	33
Rejected on account of voter being in arrears for dues on May 1, 1917, as provided in the Constitution and by-laws	102
Rejected on account of having reached the Secretary's office after May 1, according to Art. VI, Sec. 34 of the Constitution	11
	146
Leaving as valid ballots	2529

These 2529 valid ballots were counted and the result is shown as follows:

For President

E. W. Rice, Jr.	2479
Scattering and blank	50

For Vice-Presidents

Frederick Bedell	2426
John H. Finney	2381
A. S. McAllister	2362
Scattering and blank	418

For Managers

Walter A. Hall	2454
E. H. Martindale	2449
William A. Del Mar	2446
Wilfred Sykes	2437
Scattering and blank	330

Digitized by Google

For Treasurer

George A. Hamilton	2459
Scattering and blank	70

Respectfully submitted,
H. B. P. WRENN, *Chairman*
FRANK H. BEALL,
H. B. HAMMOND,
May 4, 1917. *Committee of Tellers.*

THE ENGINEERING COUNCIL

The Engineering Council is the outcome of several independent movements which took definite shape early during the present year. For a long time individual engineers and the engineering societies have considered the desirability of having some properly constituted organization empowered to speak in the name of engineers in general upon subjects of common interest to engineers and to the public. The need of such an organization in the interest of cooperation and uniformity of action on matters relating to the welfare of the engineering profession was brought to the attention of the Board of Directors of the Institute at its meeting held in Philadelphia in October 1916, at which the subject was discussed at considerable length. A resolution was adopted at that meeting authorizing the President to appoint a committee of five members of the Board and to invite the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Institute of Mining Engineers, to appoint similar representatives upon a joint committee with a view to formulating some plan of action for organizing such a central body. A series of conferences of the representatives appointed as a result of this action followed, and after considering numerous suggestions the conferees formulated a plan to amend the by-laws of the United Engineering Society so as to provide for a new department of that Society, to be known as The Engineering Council. These amendments were subsequently adopted, and have been approved by the four founder societies which constitute the United Engineering Society. The object and method of organization of the Council are expressed in the by-laws as follows:

"In order to provide for convenient co-operation between the four Founder Societies, for the proper consideration of questions of general interest to engineers and to the public and to provide the means for united action upon questions of common concern to engineers, the United Engineering Society shall, in addition to its other activities and entirely separate therefrom, establish, and maintain a department to be known as

ENGINEERING COUNCIL

"Each Founder Society shall have five representatives upon the Council and such representatives shall be designated by the governing body of such Society.

"The United Engineering Society shall have four representatives on the Engineering Council who shall be chosen by its Board of Trustees; such representatives to be men not already designated by a Founder Society.

"The Council may speak authoritatively for all member societies on all public questions of a common interest or concern to engineers, unless objection be made by a majority of the representatives present of one of the Founder Societies or by one-fourth of the representatives present and voting. It shall defer any action which is opposed as aforesaid; such suspended action shall be referred to the governing bodies of the societies whose representatives have protested, for an expression of opinion of a veto upon further action, and may then be reconsidered if such societies have agreed.

"The Council shall elect annually (at its annual meeting) from the representatives a Chairman, and two Vice-Chairmen; also a Secretary who may or may not be a representative.

"The expenses of the Engineering Council shall be disbursed out of such funds as the Trustees of United Engi-

Digitized by Google

neering Society shall from time to time provide for that purpose.

"The Engineering Council shall hold an annual meeting in New York in the month of February and such other meetings as the Council may decide.

"A quorum shall consist of one-third of the total number of representatives upon the Council.

"An Executive Committee to serve one year shall be constituted of six members, of which the Chairman, and two Vice-Chairmen shall be members. It shall transact necessary business between meetings of the Council, but shall take no action binding the Council upon debatable questions of engineering concern.

"The Council shall have authority to make rules for its own guidance, not inconsistent with these by-laws.

"The Trustees of the United Engineering Society may elect to membership in the Engineering Council other National Engineering or Technical Societies, under such rules as the Council prescribes provided their nomination and said rules have the unanimous approval of the governing bodies of the four Founder Societies.

"The Council shall keep a record of its proceedings and transmit, after each meeting, a copy of the same to the Board of Trustees of the United Engineering Society.

The following men have been appointed as the representatives of the A.I.E.E.: H. W. Buck, E. W. Rice, Jr., N. A. Carle, P. Junkersfeld and C. E. Skinner.

DIRECTORS' MEETING, MAY 18, 1917

The regular monthly meeting of the Board of Directors of the Institute was held at Institute headquarters, New York, on May 18, 1917, at 3:30 p.m.

There were present, President H. W. Buck, New York; Vice Presidents C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., B. A. Behrend, Boston, Mass., L. T. Robinson, Schenectady, N. Y.; Managers A. S. McAllister, New York, John B. Taylor, Schenectady, N. Y., Harold Pender, Philadelphia, Pa., C. E. Skinner, Pittsburgh, Pa., N. A. Carle, Newark, N. J., Charles Robbins, Pittsburgh, Pa.; Treasurer George A. Hamilton, Elizabeth, N. J., and Secretary F. L. Hutchinson, New York.

The action of the Finance Committee in approving monthly bills amounting to $11,487.01 was ratified.

Upon the recommendation of the Meetings and Papers Committee an Institute meeting was authorized to be held in Philadelphia, Pa., early in October 1917, under the auspices of the Philadelphia Section.

The report of the Board of Examiners of meetings held on April 26, May 3, and May 11 was read and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners, the following action was taken upon pending applications. Sixty-seven students were ordered enrolled, 135 applicants were elected to the grade of Associate, 9 applicants were elected to the grade of Member, one applicant was elected to the grade of Fellow, 4 applicants were transferred to the grade of Fellow, 8 applicants were transferred to the grade of Member, and 4 applicants were re-elected to the grade of Associate.

The Annual Report of the Board of Directors for the fiscal year ending April 30, 1917, which had been prepared by the Secretary, was approved for presentation at the Annual Meeting in the evening. This report is published in this issue of the PROCEEDINGS.

The annual report of the Treasurer for the fiscal year was presented and accepted.

Mr. F. L. Hutchinson was unanimously reappointed secretary of the Institute for the administrative year beginning August 1, 1917.

A considerable amount of other business was transacted by the Board, reference to which will be found in this and future issues of the PROCEEDINGS.

Digitized by Google

RULES GOVERNING PRESENTATION AND DISCUSSION OF PAPERS AT INSTITUTE MEETINGS

At the meeting of the Board of Directors held on May 18, the following rules governing the presentation and discussion of technical papers at Institute meetings, which had previously been prepared and recommended for adoption by the Meetings and Papers Committee, were approved by the Board for trial, and the committee was authorized to put them into effect at coming Institute meetings.

1. At technical sessions papers may be read by title only or by abstract, as determined by the Meetings and Papers Committee.

Papers Presented by Title

2. Papers which in the opinion of the Meetings and Papers Committee are of interest to only a limited number of members, or which cannot be well covered by oral presentation or discussion, *will* be presented by title. The author *will* be notified of this fact upon acceptance of his paper. Written discussion of such papers received by the Editor within 30 days after the presentation of the paper *will* be published in the Transactions, after being submitted to the author for his criticism.

3. Papers not read by title *will* be read in abstract. The time for presentation must not exceed 20 minutes, if there is only one paper to be presented at the session, or 10 minutes if two or more papers are to be presented.

4. Members desiring to discuss a paper should notify the Meetings and Papers Committee, or the Chairman of the meeting, in advance of the meeting. Such members *will* be allowed not to exceed 10 minutes each for discussion before any other members are given an opportunity to discuss the paper. All discussion given by a member in person will appear in the Transactions without notation.

5. Written discussion submitted in advance by an absent member may be read by the Secretary or by some member who is present, and 5 minutes may be allowed for its presentation. Such discussion will appear in the Transactions with the notation—Read or abstracted by Mr. * * * * Written discussions not read at the meeting will be marked "By letter". Later communications received within 30 days after adjournment will be printed with the notation "Communicated after adjournment".

6. In the open discussion following the presentation of the discussion by letter and by members who have given advance notification, each member will be allowed 5 minutes unless additional time is available after all others who desire to speak have been heard.

7. All discussions are subject to the acceptance and correction of the Editing Committee before publication.

8. The above rules for the presentation and discussion of papers may be altered by arrangement in advance with the Meetings and Papers Committee; by the Chairman of the session in his discretion; or, by unanimous consent of the meeting.

VALUABLE GIFT TO LIBRARY

At the meeting of the Board of Directors of the Institute held May 18, reference was made to a valuable addition to the Library's resources on the history of electricity which has been recently made, through the gift by Mr. Theodore N. Vail of 505 volumes, none of which was already in our collection. The books are chiefly French and German and include many which are now hard to obtain. The volumes presented to this Library have been selected from the Dering collection, which was purchased by Mr. Vail and presented to the Massachusetts Institute of Technology, with the understanding that the duplicates were to be given to this Library.

Digitized by Google

The following resolutions were unanimously adopted:

WHEREAS, Theodore N. Vail, Esq., has presented to the Library of the American Institute of Electrical Engineers over five hundred volumes pertaining to Electrical Engineering and the allied sciences, be it

RESOLVED, that the Board of Directors of the Institute, representing its membership, desires to express its appreciation of his generosity and thoughtfulness in rendering this collection accessible to all engineers, and be it further

RESOLVED, that a copy of these resolutions be sent to the esteemed donor.

PAST SECTION MEETINGS

Atlanta.—May 9, 1917, Chamber of Commerce. Illustrated address by Mr. M. C. Turpin on "Steam Railway Electrification". Attendance 105.

Baltimore.—March 9, 1917, Johns Hopkins University. Illustrated address by Dr. S. W. Stratton on "Work of the Bureau of Standards". Attendance 150.

April 20, 1917, Hotel Rennert. Paper: "Submarine Cable Signalling" by General Squier. Paper was read by Dr. L. M. Potts. Attendance 25.

Boston.—May 8, 1917, Engineers Club. Address by Major Chase on "The Signal Corps and Its Duties in the Field". Election of officers for the coming season as follows—chairman, Harry M. Pope; vice-chairman, L. W. Abbott; secretary-treasurer, I. M. Cushing. Attendance 75.

Chicago.—April 23, 1917, Western Society of Engineer's Rooms. Paper: "Economical Industrial Applications of Electricity" by Norman T. Wilcox. Attendance 60.

Cleveland.—March 19, 1917, Electrical League, Statler Hotel. Illustrated address by Mr. Allard Smith on "Use of Electricity in the Handling of Freight in Railroad and Ship Terminals". Attendance 36.

April 16, 1917, Electrical League, Hotel Statler. Illustrated address by Mr. Ben Perris on "Illuminating Engineering in the Motion Picture Industry". Attendance 48.

Denver.—April 20, 1917, Denver Athletic Club. Addresses by Colonel R. N. Getty and Lieutenant Scott of Fort Logan, and Lieutenant Miller of the Naval Recruiting Station on "The General Requirements of Military and Naval Engineering". Attendance 64.

Detroit-Ann Arbor.—April 20, 1917, Detroit Engineering Society Rooms. Paper: "Thermo-Electric Pyrometry" by R. B. Lincoln. Attendance 100.

April 27, 1917, Detroit Engineering Society Rooms. Paper: "Alternating-Current Motors" by B. F. Bailey. Attendance 40.

Fort Wayne.—May 10 and 11, 1917, Moose Hall. Electrical Exhibition. Display of electrical devices used in the home. Attendance 1200.

Indianapolis-Lafayette.—April 20, 1917, Indianapolis. Paper: "Engineering and Telephone Wire Plant" by B. D. Wilber. Attendance 27.

Milwaukee.—April 16, 1917, City Club. Illustrated addresses by Messrs. H. O. Seymour and W. D. Hobbins on "The Main Office Building of the Wisconsin Telephone Company, Broadway, Milwaukee". Attendance 90.

Minnesota.—April 20, 1917, University of Minnesota. Address by Mr. Arnold Pfau on "Modern Hydraulic Turbines and Hydroelectric Units". Attendance 270.

Panama.—April 15, 1917, Pacific Forts, Panama Canal. Inspection trip through the Pacific Fortifications of the Panama Canal. Attendance 84.

Philadelphia.—March 8, 1917, Franklin Institute. Paper: "Dielectric Losses in Insulating Materials" by C. E. Skinner. Joint meeting with Franklin Institute. Attendance 100.

March 12, 1917. Engineers Club. Paper: "Recent Developments in the Use of Vacuua" by Saul Dushman. Attendance 135.

April 9, 1917, Engineers Club. Paper: "Underground Cables and Their Use in Modern Practise" by H. W. Fisher. Attendance 100.

Pittsfield.—April 13, 1917, Hotel Wendell. Paper: "Patents and Patent Law" by A. G. Davis. Attendance 100.

Digitized by Google

April 26, 1917, Hotel Wendell. Paper: "Selecting and Testing of Materials" by J. A. Capp. Attendance 80.

Rochester.—March 23, 1917. Paper: "Polyphase Commutator Motors" by Vladimir Karapetoff. Attendance 61.

April 27, 1917, Rochester Engineering Society Rooms. Paper: "International Electrical Standards" by A. S. McDaniel. Attendance 27.

Schenectady.—April 20, 1917, Edison Club. Address by Dr. C. R. Mann on "A New Basis of Engineering Education". Attendance 200.

Election of officers for the coming year as follows—chairman, W. L. Upson; vice-chairmen, T. A. Worcester, H. Maxwell and O. J. Whitecotton; secretary, L. F. Milham; treasurer, L. Rask.

May 4, 1917, Edison Club. Illustrated address by Mr. J. B. Taylor on "Acoustical Engineering and a Review of the Characteristics of Noise, Speech, and Musical Sound". Attendance 250.

Seattle.—April 17, 1917, Arctic Building. Address by Captain John Harisberger Engineer Officers Reserve Corps, on "War Department's Plan for the Organization of the Engineer Officers Reserve Corps". Attendance 51.

Spokane.—April 20, 1917, Old National Bank Assembly Room. Papers: (1) "Electrolysis" by F. L. Rohrback; (2) "Transformers" by V. H. Greisser. Attendance 32.

St. Louis.—April 25, 1917, Engineers Club Room. Illustrated address by Mr. M. C. Turpin on "Electrification of Steam Railways". Attendance 51.

Toledo.—April 18, 1917, Toledo Commerce Club. Illustrated lecture by Mr. C. W. McKinley on "Some of the Problems of Automobile Designing". Attendance 19.

May 2, 1917, Toledo Commerce Club. Address by Mr. A. E. Buchenberg on "Electric Welding". Attendance 25.

Toronto.—April 20, 1917, Engineers Club. Address by Mr. E. V. Pannell on "Rapid Transit Railways". Election of officers for the coming year as follows—chairman, Wm. G. Gordon; secretary, Ernest V. Pannell. Attendance 27.

Urbana.—March 21, 1917, University of Illinois. Paper: "The City of Chicago Street Lighting System" by A. B. Gates. Attendance 60.

Washington.—April 24, 1917, Cosmos Club. Paper: "Measurement of Temperature in Electrical Engineering" by L. T. Robinson. Attendance 32.

PAST BRANCH MEETINGS

University of Arkansas.—April 16, 1917. Lecture by Prof. G. E. Ripley on "Opportunities for Young Men in Arkansas". Two reel motion picture on "Asphalt Road Construction". Attendance 21.

Armour Institute.—April 10, 1917. Paper: "The Owen Magnetic Transmission" by E. D. Porges. Attendance 23.

April 24, 1917. Address by Mr. Robert Randolph on "The Possibilities of the Drainage Canal as a Military Asset". Attendance 46.

Polytechnic Institute of Brooklyn.—April 20, 1917, Mailloux Library. Papers: (1) "Handling of Supplies for Central Stations" by F. L. Leitner; (2) "Three-Phase Four-Wire Low-Tension Distribution" by A. H. Bernhard. Attendance 21.

May 4, 1917. Experimental lecture on "Color" by Mr. Robert von Nardoff. Attendance 100.

University of California.—April 11, 1917. Address by Mr. H. H. Anderson on "Electrolysis Survey of Electric Railways". Election of officers for ensuing year as follows—chairman, Bradley B. Brown; vice-chairman, W. R. Kemper; treasurer, M. L. J. Frandy; secretary, H. E. Fielder. Atttendance 23.

Highland Park College.—March 15, 1917, College Auditorium. Paper: "Public Utility Relations" by Secor Cunningham. Attendance 88.

Iowa State College.—April 18, 1917. Paper: "Electric Rates for Residences" by George Brush. Attendance 37.

Digitized by Google

University of Kansas.—April 25, 1917, Marvin Hall. Papers: (1) "Electric Welding" by C. Lynn; (2) "Railway Electrification" by T. Q. Morton. Attendance 18.

May 9, 1917, Marvin Hall. Address by Mr. R. W. Davis on "Oil Wells". Election of officers for the coming year as follows—chairman, R. W. Davis; vice-chairman, C. Lynn; secretary-treasurer, Clark Davis; executive committee, F. E. Johnson, H. Gish, C. A. Keener, J. J. Jakowsky. Attendance 22.

Lehigh University.—April 19, 1917. Paper: "Water Power Legislation" by R. S. Wenner. Attendance 47.

University of Minnesota.—May 7, 1917, Engineering Auditorium. Illustrated lecture by Mr. E. K. Read on "Circuit Breakers". Attendance 12.

University of Missouri.—April 26, 1917, Engineering Building. Paper: "Railroad Electrification" by M. C. Turpin. Attendance 46.

University of North Dakota.—April 24, 1917. Subject: Illumination. Speakers: Messrs. Fred T. Hicks, D. F. McConnell and J. F. Stevens. Election of officers as follows—president, David F. McConnell; secretary, Roy A. Wehe.

May 4, 1917. Paper: "Switchboards and Switchboard Equipment" by E. K. Read. Paper illustrated by lantern slides. Attendance 12.

Ohio State University.—April 20, 1917, Robinson Laboratory. Address by Mr. Kalb on "Carbon Dynamo Brushes". Attendance 28.

April 27, 1917, Robinson Laboratory. Paper: "The Steel Industry" by C. E. Winegartner. Attendance 26.

University of Oklahoma.—May 8, 1917, Engineering Building. Joint meeting with local branch of A.S.M.E. Illustrated lecture on "Illumination" by Professors Woods and Morrow. Annual address by Chairman H. M. Richards. Address by President of A.S.M.E. Election of officers as follows—chairman, O. W. Watter; vice-chairman C. T. Hughes; secretary, C. H. Whitwell; treasurer, R. A. Hoffman. Attendance 27.

Pennsylvania State College.—May 15, 1917. Paper: "Automatic Telephone" by C. H. Mills. Attendance 35.

University of Pittsburgh.—May 1, 1917, Thaw Hall. Address by Mr. H. H. Clark on "Electrical Mine Safety Appliances". Attendance 60.

Syracuse University.—May 3, 1917. Lectures as follows—(1) "Oil Switches" by H. L. Bowman; (2) "A Quarter of a Century of the Electric Utility Business and What It Has Taught" by M. O. Dell Plain. Attendance 50.

May 10, 1917. Moving picture of Pittsfield Works of General Electric Company. Attendance 35.

Virginia Polytechnic Institute.—April 26, 1917, German Club Hall. Three reel motion picture on "Electrical Control of the Panama Canal". Attendance 252.

Washington State College.—April 13, 1917, Van-Dorren Hall. Address by Professor Waller on "The Keechelus Dam". Attendance 48.

May 4, 1917. Address by Prof. Steele on "Fundamental Engineering Unit". Attendance 25.

Yale University.—May 9, 1917, 10 Hillhouse Avenue. Lecture by Prof. H. V. Bozell on "The Signal Corps of the United States Army". Attendance 90.

ASSOCIATES ELECTED MAY 18, 1917

AMBUHL, F. F., Engineer, Toronto Hydroelectric System, 226 Yonge St.; res., 795 College St., Toronto, Ont.

ARMSTRONG, HARRY H., Assistant Electrical Engineer, Ford Motor Co.; res., 926 Sheridan Ave., Detroit, Mich.

BAKER, LOUIS AMIEL, Engineer, Power Engineering Div., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 403 Whitney Ave., Wilkinsburg, Pa.

BAKER, ROBERT, Leading Draftsman and Engineer, Thomas E. Murray, 124 E. 15th St., New York; res., 15 Plainfield Ave., Lynbrook, N. Y.

BARTLETT, ALFRED EDWIN, Construction Dept., General Electric Co.; res., 213 Seward Pl., Schenectady, N. Y.

Digitized by Google

BELL, RALPH STEWARD, Stations Dept., Toronto Hydroelectric System; res., 10 Starr Ave., Toronto, Ont.

*BISHOP, EUGENE ALONZO, Draughtsman, Commonwealth Edison Co.; res., 1043 Catalpa Ave., Chicago, Ill.

BODENBACH, ROBERT P., Electrician, Cutler-Hammer Mfg. Co.; res., 702 35th St., Milwaukee, Wis.

BONHAM, LESTER D., Engineer, Colorado Power Co., 828 Symes Bldg.; res., 1230 Monroe St., Denver, Colo.

BOWDITCH, ROY, Superintendent, Electrical Engineering Dept., Merchants Heat and Light Co., Indianapolis, Ind.

BROOKE, BENJAMIN F., Assistant Division Operator, Pennsylvania Railroad Co.; res., 1515 N. 55th St., Philadelphia, Pa.

BROWN, CARROL G., Laboratory Director, Rochester Railway & Light Co.; res., 215 Weldon St., Rochester, N. Y.

BURGESS, HOWARD OTIS, Assistant Engineer, Bangor Railway & Electric Co.; res., 40 Second St., Bangor, Me.

CANN, JOHN OSMOND GILBERT, Marconi Wireless Telegraph Co., 137 McGill St., Montreal, Que.

CARR, JAMES M., Electrical Instructor, Cass Technical High School; res., 27 Forsyth St., Detroit, Mich.

CAVANAGH, JOHN F., Electrical Engineer, Connecticut Telephone & Electric Co.; res., 41 Cook Ave., Meriden, Conn.

CLAPP, DUDLEY, Assistant Engineer, Federal Power & Light Co., 35 Congress St., Boston; res., 52 Hartford St., Dorchester, Mass.

CLARK, CHARLES E., Electrical and Illuminating Engineer, Woodill & Hulse Electric Co.; res., 1961 Lovelace Ave., Los Angeles, Cal.

CLARKE, CHARLES F., Junior Engineer, with Harold Almert; res., 1325 Astor St., Chicago, Ill.

*CONNER, GEORGE CARTNELL, Manager, Lamp Dept., Pettingell-Andrews Co., Boston; res., 50 Greaton Rd., West Roxbury, Mass.

COOPER, SAMUEL CHARLES, Electrical Engineering Assistant, Traffic Dept., Western Union Telegraph Co., New York, N. Y.; res., 419 Livingston St., Elizabeth, N. J.

DARLINGTON, GEORGE PALMER, Inspector, Stone & Webster Engineering Corp., Boston; res., 273 High St., Medford, Mass.

DAY, RICHARD FOULKE, Engineer, Day & Zimmerman, 611 Chestnut St., Philadelphia, Pa.

DEGENER, FRED S., Assistant Electrical Engineer, Ford Motor Co.; res., 49 Lewerenz Ave., Detroit, Mich.

DOWNEY, HARRY J., Assistant Electrical Engineer, Ford Motor Co., Detroit; res., 224 Glendale Ave., Highland Park, Mich.

DOWNIE, ROBERT JAMES, Electrician, Union Iron Works, San Francisco; res., 1614 Minturn St., Alameda, Cal.

EMERSON, WILLIAM RALPH, Secretary & Treasurer, Muskogee Gas & Electric Co., 23 Okmulgee Ave., Muskogee, Okla.

ENGELMANN, JOHN L., Engineering Draftsman, Electric Products Co.; res., 1121 E. 148th St., Cleveland, O.

ENNIS, WILLIAM HERMAN, Contracting Electrical Engineer, 821 Union St.; res., 2025 Perdido St., New Orleans, La.

*ESHBACH, OVID W., Instructor in Electrical Engineering, Lehigh University; res., 323 Packer Ave., So. Bethlehem, Pa.

FAGGE, WILLIAM ERNEST, Foreman Electrician, Counties Gas & Electric Co.; res., 146 Crickett Ave., Ardmore, Pa.

*FERNANDES, JOSE MANUEL, Sales Dept., Brazilian General Electric Co., Rua Dezembargador Izidro 110, Rio de Janeiro, Brazil, South America.

FISCHER, CARL WILLIAM, Senior Draftsman, Station Layout and Design, Commonwealth Edison Co., 72 W. Adams St., Chicago, Ill.

FISHER, CHARLES HEBER, Engineering Dept., Du Pont Powder Co., 834 Du Pont Bldg., Wilmington, Del.

Digitized by Google

FORDE, WILLIAM H., Salesman, Electric Storage Battery Co., 720 Beacon St., Boston, Mass.

FOSTER, O. LENEVE, Consulting Engineer, 704 Harris Trust Bldg., Chicago; res., 2710 Woodbine Ave., Evanston, Ill.

*FRANK, MILTON H., Operating Engineer, Galesburg Railway, Lighting and Power Co., 7 E. Main St.; res., 169 E. Ferris St., Galesburg, Ill.

GAMPER, GUSTAVE HERMAN, Consulting Electrical and Mechanical Engineer, 421 New 1st National Bank Bldg., Columbus, O.

GRANT, LAURENCE HOWARD, Armature Winder and Power Station Operator, Fresno Traction Co.; res., 1435 Eye St., Fresno, Cal.

GREEN, ARTHUR WILLIAM GRAHAM, Supply Sales Dept., Northern Electric Co. Ltd., 121 Shearer St., Montreal, Que.

GUY, WILLARD T., Electrical Engineer, Maxwell Motor Co.; res., 260 Stanton Ave., Detroit, Mich.

HANSEN, OSCAR, Junior Electrical Engineer, Dept. of Gas and Electricity, City of Chicago; res., 1723 Chase Ave., Chicago, Ill.

HARALSON, NEWTON MCCRAW, Engineer, Service Dept., Westinghouse Electric & Mfg. Co.; res., 803 South 49th St., Philadelphia, Pa.

HAZARD, FLOYD HAMILTON, Fire Alarm and Fire Dept. Engineer, National Board of Fire Underwriters, 76 William St., New York, N. Y.

HORR, EDWARD N., Cadet Engineer, Counties Gas & Electric Co., 212 De Kalb St., Norristown, Pa.

HUNTER, RUSSELL NORMAN, Electrical Research Assistant, Massachusetts Institute of Technology; res., 63 Dana St., Cambridge, Mass.

HUTCHINS, WILLIAM JOHN MORGAN, Chief Clerk, Engineering Dept., Tri-State Tel. Co.; res., 64 S. Avon St., St. Paul, Minn.

IRWIN, A. EARL, Electrical Engineer, Kimball, Neb.

JACOBS, GEORGE AMIDON, Manager, Dudlo Mfg. Co.; res., 1302 W. Washington St., Ft. Wayne, Ind.

JOHNSON, CLARENCE NATHAN, Industrial Sales Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 483 Campbell St., Wilkinsburg, Pa.

*JONES, WILLIAM ELWIN, Testing Dept., Commonwealth Edison Co.; res., 5426 Race Ave., Chicago, Ill.

KEELER, EARL ALTON, Experimental Dept., Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia; res., 637 Haws Ave., Norristown, Pa.

*KELLER, CONSTANTINE CHARLES, Engineering Inspector of Transmitters and Receivers, Automatic Electric Co.; res., 1513 Monroe St., Chicago, Ill.

KENNEDY, SCOTT JOSEPH, Foreman of Construction and Maintenance, Great Western Power Co.; res., 1516 First Ave., Oakland, Cal.

KEY, HOWARD WILLIAM, Manager, Small Motor Dept., General Electric Co.; res., 401 Williams St., Atlanta, Ga.

KOBAK, EDGAR, Editorial Representative, *Electrical World*; res., 15 Arden St., New York, N. Y.

KREIS, JOHN GEORGE, Electrical Engineering Laboratory Assistant, Acme Wire Co., New Haven; res., North Haven, Conn.

KROGMAN, WERNER W., Assistant to Manager of Electrical Dept., Chicago Pneumatic Tool Co., Chicago; res., 229 S. Kenilworth Ave., Oak Park, Ill.

KROUT, PALLED B., Superintendent of Construction, Pennsylvania Railroad Co., Philadelphia; res., 203 Elm Terrace, Narberth, Pa.

LAING, NORMAN B., Electrical Engineering Staff, Ford Motor Co.; res., 73 Willis Ave. East, Detroit, Mich.

LAUDER, ANDREW ROBERT K., Electrical Engineer, General Electric Co.; res., 923 State St., Schenectady, N. Y.

LAWSON, JOEL SMITH, Sales Engineer, R. Thomas & Sons Co., Room 1424, 61 Broadway, New York, N. Y.

Digitized by Google

LEWIS, ALEXANDER THORNTON, Member of Firm, Lewis, Robinson & Gaut, 1303 Land Title Bldg., Philadelphia, Pa.

LINEBERRY, EDWARD, Assistant Engineer, Public Service Terminal Building; res., 762 S. 20th St., Newark, N. J.

LITCHFIELD, ROBERT BACH, Engineering Dept., New York Telephone Co., 15 Dey St., New York, N. Y.

LORENZ, CHARLES F., Physicist, National Lamp Works General Electric Co., Nela Park, Cleveland, O.

LOY, JAMES MCNEAL, Draughtsman, Assistant Engineer's Office, Pennsylvania Railroad Co.; res., 2527 Broad Ave., Altoona, Pa.

MACDONALD, WILLIAM GRANT, Commercial Engineer, Power Sales Dept., Nova Scotia Tramways & Power Co. Ltd., Halifax, N. S.

MAGNUS, MORTON H. A., Chief Electrician, *New York American*, New York; res., 2065-78th St., Brooklyn, N. Y.

MANWARING, MYRON. Superintendent, Power Plant Dept., Murray City Corp., Murray, Utah.

MATSON, C. H., Engineer, Factory, General Electric Co.; res., 931 Liberty St., Fort Wayne, Ind.

MCALLISTER, ELVY G., Draftsman, Electric Service Supplies Co., Philadelphia, Pa.; res., 645 Royden St., Camden, N. J.

MCCORMICK, ROBERT J., Assistant Electrical Engineer, Ford Motor Co., Detroit; res., 194 Louise Ave., Highland Park, Mich.

MCKAY, JOHN ARCHIBALD, Electrician, Tallassee Power Co., Badin, N. C.

MCKEE, MYRON, Electrical Engineer, Ford Motor Co.; res., 94 Warren Ave. East, Detroit, Mich.

MCKINNELL, DAVID MORRIS, Electrical Foreman, Stone & Webster Engineering Corp., New Bedford, Mass.

MENTZEL, JULIUS R., Superintendent of Electrical Distribution, Oshkosh Gas Light Co.; res., 99 Rosalia St., Oshkosh, Wis.

MERWIN, F. R., Superintendent, F. E. Newbery Electric Co.; res., 4929 Perrier St., New Orleans, La.

MIKALOFF, JOHN PETER, JR., Electrician, Lewis & Roth; res., 2037 Chestnut St., Philadelphia, Pa.

MILLAR, HAROLD H., Inspector in Charge, Oakland Bureau, Electrical Testing Laboratories, 1648 16th St., Oakland, Cal.

MILLER, HAROLD P., Meterman, Consolidated Power & Light Co.; res., 97 Forrest Ave., Deadwood, S. D.

MILLS, HARRY AKERS, Electrical Engineer, Colorado Power Co.; res., 618 Downing St., Denver, Colo.

MOMBERGER, WILLIAM JULIUS, Engineer, Gibbs & Hill, Pennsylvania R. R. Station, New York, N. Y.

MOORE, EUGENE BOISE, Sales Engineer, Allis-Chalmers Manufacturing Co., 819 Ohio Bldg., Toledo, O.

MORGAN, CLINTON WILKINS, Salesman Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 410 Franklin Ave., Wilkinsburg, Pa.

MORRELL, EDWARD STEVENS, Assistant Superintendent, Pennsylvania Railroad Co., Broad Street Station; res., 1319 Ontario St., Philadelphia, Pa.

*MUNYAN, EARL ADDIS, Supervisor, Gun Cotton Dept., "B" Plant, E. I. du Pont de Nemours & Co.; res., Du Pont Hotel, City Point, Va.

MURRAY, ARTHUR HADLEY, Plant Electrical Engineer, Engineer in charge of Testing Laboratory, Standard Underground Cable Co. of Canada, Ltd., Sherman Ave., Hamilton, Ont.

OBER, EARLE MYRON, Traffic Engineer, B. C. Telephone Co. Ltd., Vancouver, B. C.

O'DAIR, WILLIAM J., Assistant Electrical Engineer, Lewis H. Woods, 2355 Jerome Ave., New York, N. Y.

*OSTER, EUGENE A., Mechanical Engineer, Ault & Wiborg Co.; res., 1065 Wade St., Cincinnati, O.

OWENS, GEORGE MICHAEL, Chief Electrician, Springfield Body Co.; res., 13 Begole St., Detroit, Mich.

Digitized by Google

*PASZKIEWICZ, JOSEPH ANTHONY, Private Instruction and Translation Work; res., 1248 Noble St., Chicago, Ill.

*PERKINS, HARRY R., Electrical Engineer, Ford Motor Co., Detroit; res., 233 Greenwood Ave., Birmingham, Mich.

PIHL, CARL ALBION, Testing Dept., General Electric Co.; res., 234 Second St., Pittsfield, Mass.

PORTA, PETER PASQUAL, Foreign Dept., Otis Elevator Co., New York, N. Y.

POTTS, HOWARD BLANCHARD, Master Mechanic, National Coal Co., Byesville, O.

*POWELL, EDGAR JOHN, Engineer, Electrical Dept., D. L. & W. R. R. Co., Scranton; res., Clarks Summit, Pa.

PUTNAM, WILLIAM JAMES, Instructor in Theoretical & Applied Mechanics, University of Illinois; res., 610 W. Illinois St., Urbana, Ill.

*REIS, MAVIS DE OLIVEIRA, Instructor, Engineering School of Porto Alegre, Rio Grande do Sul, Brazil, South America.

RHODES, MILTON ARTHUR, Electrical Superintendent, McLaughlin Engineering Co., Gilmore City, Ia.

ROBINSON, GEORGE NELSON, Machinery Sales Dept., General Electric Co., 1236 First National Bank Bldg., Denver, Colo.

RUEGG, ARNOLD, Foreman, Electrical Maintenance and Construction, Falk Co.; res., 3317 McKinley Blvd., Milwaukee, Wis.

SALISBURY, ROYAL DUNKLE, Engineer, 1455 Gaylord St., Denver, Colo.

SANDIG, GEORGE CURT, Asst. Foreman, Electric Meter Dept. and Laboratory, Denver Gas & Electric Light Co.; res., 3437 Julian St., Denver, Colo.

SAPERSTON, Q. NATHAN, Power Engineer, Western Electric Co.; res., 3820 Arthington St., Chicago, Ill.

SCHIRTZINGER, LEO, Sales Engineer, John McC. Price Co., 301 Mfg. Bldg.; res., 2022 Osgood St. N.S., Pittsburgh, Pa.

*SIGMAN, JOSEPH, Electrical Contracting and Sales Engineer, X-L Electric Co.; res., 1627 S. 8th St., Philadelphia, Pa.

SMITH, HARRY JAMES, Chief Draftsman, Sierra & San Francisco Power Co.; res., 180 Alpine Terrace, San Francisco, Cal.

*SMITH, IRVING THOMAS, JR., Assistant Power Engineer, Edison Electric Illuminating Co. of Brooklyn; res., 860 St. Marks Ave., Brooklyn, N. Y.

SMITH, ROBERT COWL, Draftsman, Columbus Railway, Power & Light Co.; res., 124 King Ave., Columbus, O.

SMITH, ROTHWELL EVERETT, Engineer's Assistant, Lowell Dist., New England Tel. & Tel. Co.; res., 69 Hastings St., Lowell, Mass.

STEELE, EDWARD HARRISON, Electrical Enginer, New Bedford Gas & Edison Light Co.; res., 21 Bay St., New Bedford, Mass.

STINSON, WILLIAM LOUIS, Engineer, Public Service Electric Co.; res., 281 Woodside Ave., Newark, N. J.

*STOKES, PAUL FREDERICK, Assistant Manager, Nela Lamp Div., General Electric Co., Nela Park, Cleveland, O.

STUART, FREDERICK CHARLES, Signal Engineer, Elgin, Joliet & Eastern Ry. Co.; res., 113 N. Center St., Joliet, Ill.

SULLIVAN, JOHN S. B., Inspector, Stone & Webster Engineering Corp., 60 S. Plymouth Ave., Rochester, N. Y.

THOMAS, RAYMOND S., Electrician, Bartlesville Zinc Co.; res., 629 W. Bridge St., Blackwell, Okla.

TODD, WILLIS, Vice-President, Union Co. of Omaha, 424 First National Bank Bldg.; res., 210 N. 53rd Ave., Omaha, Neb.

TOLL, LOUIS C., Foreman, Motor Generator Dept., Electric Products Co.; res., 11708 Ohlman Ave., Cleveland, O.

TYSON, EDWIN HUMES, Supt., Meter Dept., Lehigh Valley Light & Power Co.; res., 703 N. 12th St., Allentown, Pa.

Digitized by Google

UNDERHILL, HOWARD J., Superintendent, Range Div., Great Northern Power Co.; res., 516 Cook St., Virginia, Minn.

WALRATH, ANDREW J., Electrical Engineer, Ford Motor Co., Detroit; res., 443 Monterey Ave., Highland Park, Mich.

WATSON, JOHN N. MICHAEL, Engineering Dept., Western Electric Co., 463 West St., New York; res., 2033 Palmetto St., Brooklyn, N. Y.

WEBSTER, EVANS, Head of Department of Physics, Lynn English High School; res., 11 Sachem Terrace, Lynn, Mass.

WEEMAN, HERBERT FRANCIS, Assistant Electrical Engineer, Ford Motor Co., Detroit; res., 250 Fanand Park Ave., Highland Park, Mich.

WEIR, ROBERT PHILIP, Sales Engineer, Cutter Electrical & Mfg. Co., 923 Traders Bank Bldg.; res., 170 Geoffrey St., Toronto, Ont.

WENTWORTH, HERBERT HIRAM, Railway Engineering, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 512 Franklin Ave., Wilkinsburg, Pa.

WHITE, EDWARD JOSEPH, Electrical Construction Foreman, Public Service Electric Co.; res., 41 Oraton St., Newark, N. J.

WILLIAMSON, HENRY MERLE, Telegrapher, Paine, Webber & Co.; res., 1753 W. 56th St., Chicago, Ill.

WINN, CLAUD E., Supervisor, Foreign Crossing, Parallelisms & Inductive Interference, Western Union Telegraph Co.; res., 6159 Kenwood Ave., Chicago, Ill.

WOLFE, NOBLE A., Electrical Engineer, Industrial Control, General Electric Co.; res., 642 Terrace Place, Schenectady, N. Y.

WOODFIELD, ARTHUR MONTGOMERY, Engineer and Estimator, 1727 Sansom St.; res., 227 S. 41st St., Philadelphia, Pa.

WRIGHT, ELMER H., Electrical Construction, 1753 Monterey Ave., Chicago, Ill.

WRIGHT, FRANK VAN ZANDT, Superintendent of Operation, Western Colorado Power Co., Silverton, Colo.

Total 135.

*Former enrolled Students.

ASSOCIATES RE-ELECTED, MAY 18, 1917

DAVIDSON, JAMES E., Assistant to the President, Omaha Electric Light & Power Co., Omaha, Neb.

HERTZ, STANTON S., Tester (Electrical), Dynamo Testing Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 726 Wallace Ave., Wilkinsburg, Pa.

MCAFEE, ALLAN LINDSAY, Electrical Engineer, Superintendent and Estimator, W. I. Gray & Co., 914 Mary Pl., Minneapolis, Minn.

PRATT, RICHARD H., Inspector for E. B. Proctor, 63 Beaver St., New York, N. Y.; res., 116 Lafayette Drive, Atlanta, Ga.

MEMBERS ELECTED, MAY 18, 1917

CATLIN, JOSEPH PRIESTLEY, Department Engineer, General Electric Co.; res., 137 Wendell Ave., Pittsfield, Mass.

COLLINS, JOHN LAMBERT, Electrical Engineer, Lowell Electric Light Corp.; res., 82 Hanks St., Lowell, Mass.

KISER, ALEXANDER BLACK, Superintendent of Electrical Equipment, Pittsburgh Coal Co., Pittsburgh; res., 52 Hawthorn Ave., Crafton, Pa.

KUHLMAN, ETNA, President, Kuhlman Electric Co., Bay City, Mich.

MANN, ALBAN WHITFORD, Electrical Engineer, Central Illinois Public Service Co., Mattoon; res., 392 Chicago St., Elgin, Ill.

NORRIS, ROLLIN, General Superintendent, United Gas Improvement Co., Broad & Arch St., Philadelphia, Pa.

RANDOLPH, CHARLES PHILIP, Managing Engineer, Heating Device Dept., General Electric Co., Pittsfield, Mass.

Digitized by Google

TAYLOR, ALFRED JAMES TOWLE, Consulting Engineer, 607 Credit Foncier Building, Vancouver, B. C.

TILLSON, BENJAMIN FRANKLIN, Head of Mining Department; Mechanical & Electrical Engineering, New Jersey Zinc Co., Franklin Furnace, N. J.

FELLOW ELECTED, MAY 18, 1917

ALLISON, FRED, Chief Electrical Engineer, Ford Motor Co.; res., 211 Rosedale Ct., Detroit, Mich.

RECOMMENDED FOR TRANSFER

The Board of Examiners recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

Recommended for Transfer by the Board of Examiners May 3, 1917.

To Grade of Fellow

BLACKWELL, OTTO B., Transmission and Protection Engineer, American Telephone & Telegraph Co., New York, N. Y.

To Grade of Member

ALEXANDER, HARRY, Electrical and Mechanical Contracting Engineer, New York, N. Y.

ANDRAE, ROBERT TURNER, Assistant General Manager, Northern Ontario Light & Power Co., Cobalt, Ont.

AUTY, K. A., Sales Engineer, Commonwealth Edison Co., Chicago, Ill.

DAVIDSON, JAMES E., Assistant to the President, Omaha Electric Light & Power Co., Omaha, Neb.

DEXTER, HARRIS EDWARD, Engineer, Industrial Control Dept., General Electric Co., Schenectady, N. Y.

GRAY, G. FRANCIS, Industrial Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.

HALL, CHESTER I., Engineer, Demand Meter Dept., General Electric Co., Ft. Wayne, Ind.

MURRAY JOSEPH BRADLEY, Assistant General Manager, Edison Electric Illuminating Co. of Brooklyn, Brooklyn, N. Y.

WRAY, EDWARD, Assistant to General Manager, Sangamo Electric Co., Springfield, Ill.

Recommended for Transfer by the Board of Examiners May 11, 1917.

To Grade of Fellow

BLAKE, S. H., Engineer, Supply Dept., General Electric Co., Schenectady, N. Y.

CRAIGHEAD, JAMES R., Electrical Engineer, Standardizing Laboratory, General Electric Co., Schenectady, N. Y.

To Grade of Member

CRYDER, Ross W., Superintendent, Lighting & Power Div., Porto Rico Railway Light & Power Co., San Juan, Porto Rico.

KELLER, C. A.., Senior Engineer, Commonwealth Edison Co., Chicago, Ill.

LESLIE, EDWARD A., Electrical Engineer, New York, N. Y.

TRANSFERRED TO THE GRADE OF FELLOW MAY 18, 1917

HEWLETT, E. M., Engineer of Switchboard Dept., General Electric Co., Schenectady, N. Y.

LYNDON, LAMAR, Consulting Engineer, New York, N. Y.

VON KROGH, KARL KONORO, Consulting Electrical Engineer, Nissen & von Krogh, Christiania, Norway.

YARDLEY, J. L. M., Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh Pa.

TRANSFERRED TO THE GRADE OF MEMBER MAY 18, 1917

BLACKBURN, LEONARD A., Electrical Engineer, E. I du Pont de Nemours & Co., City Point, Va.

CARR, WALTER DE LANCEY, Assistant to Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

Digitized by Google

HARVEY, GILBERT A., Electrical Engineer, Philadelphia Rapid Transit Co., Philadelphia, Pa.

LISTON, JOHN, Technical Writer and Lecturer, Publication Bureau, General Electric Co., Schenectady, N. Y.

LIVERSIDGE, HORACE P., Operating Engineer, Philadelphia Electric Co., Philadelphia, Pa.

LYLE, FREDERICK W., Electrical Engineer, Research Laboratory, General Electric Co., Lynn, Mass.

JAMIESON, BERTRAND C., Engineer of Inside Plant, Commonwealth Edison Co., Chicago, Ill.

SCOTT, EDGAR G., Superintendent of Power and Repairs, Ludlow Manufacturing Associates, Ludlow, Mass.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before June 30, 1917.

Allen, N. L. (Member), Mascot, Tenn.
Austin, B. O., Charlotte, N. C.
Averbach, J. E., Detroit, Mich.
Avery, F. B., St. Louis, Mo.
Badger, H. S., Chicago Heights, Ill.
Bridgman, A. D., Plainville, Conn.
Brown, E. A., Cleveland, O.
Claytor, E. M., East Pittsburgh, Pa.
Clover, E. B., Detroit, Mich.
Collins, A. B., Denver, Colo.
Connell, R., Garwood, N. J.
Covell, R. A., New Haven, Conn.
Cregar, S. C., Omaha, Neb.
Dorsey, O. B., Norwich, Conn.
Fleisher, W. A., (Member), Philadelphia, Pa.
Fleming, E., Port Chalmers, N. Z.
Forney, R. H., Dallas, Tex.
Forsyth, A. K., New York, N. Y.
Fouraker, R. S., East Pittsburgh, Pa.
Hale, W. I., City Point, Va.
Hamilton, C. P., Schenectady, N. Y.
Herrmann, L. C., Chicago, Ill.
Hutchings, F. F., Lynn, Mass.
Junkins, R. D., Midland, Pa.
King, A. A., Copper Hill, Ariz.
Kubo, K., Tokyo, Japan
Landis, C. S., Lancaster, Pa.
Langstaff, H. A. P., Niagara Falls, N. Y.
Levy, K., Colon, R. P.
Lopez, J. A., Banes, Cuba
Lucas, B. E., Detroit, Mich.
Maneckj, J. B., Khopoli, India.
McChesney, A. B., New York, N. Y.
Meyer, H. V., Wayne, Mich.
Molitor, F. W., Annapolis, Md.
Murrell, C. E., New York, N. Y.
Nickel, L. W., New York, N. Y.
Nihan, R. E. (Member), Angola, Ind.
Noome, C., Utrecht, Holland
Otten, H., Jr., New York, N. Y.
Perry, D. W., East Pittsburgh, Pa.
Pike, R. D. (Member), San Francisco, Cal.
Rodgers, C., London, England.
Roumbanis, D., Toronto, Ont.
Ryan, F. E., Spokane, Wash.
Salberg, W. H., Wickliffe, O.
Sanford, S. B., New York, N. Y.
Schloth, A. C., W. Lynn, Mass.
Sherrerd, G., Jr., East Pittsburgh, Pa.
Simonich, J. L., Midland, Pa.
Smith, B., Prescott, Ariz.
Smith, H. E., Boston, Mass.
Smolens, H., Philadelphia, Pa.
Strickland, A. L., Portland, Ore.
Thompson, C. H., Cleveland, O.
Tinson, H. A., Harrison, N. J.
Wade, W. H., Jr., Bluefield, W. Va.
Welke, R. A., New York, N. Y.
Westrap, A. T., Sivasamudram, India.
Whipple, C. L., Great Falls, Mont.
White, C. W., Rumford, Me.
Whitney, W., St. Cloud, Minn.
Wolf, C. W. W., Schenectady, N. Y.
Wood, B., Hobart, Tasmania
Wood, H. M., East Pittsburgh, Pa.
Wright, J. E., Carrizozo, N. M.
Total 66

Digitized by Google

STUDENTS ENROLLED MAY 18, 1917

8992 Dehler, R. W., Univ. of Wash.
8993 Wehe, R. A., Univ. of N. D.
8994 Strand, S., Univ. of N. D.
8995 Mueller, E.R., BrooklynPoly.Inst.
8996 Turner, H. R., Wentworth Inst.
8997 Gefke, J. H., Univ. of Wis.
8998 Loucks, C. E., Stanford Univ.
8999 Sinnen, F. E., Univ. of Wis.
9000 Clark, J. St. C., Univ. of Okla.
9001 Fuchs, J. W., A & M Coll. of Tex.
9002 Bridgwater, M. M., A.&M. Coll. of Tex.
9003 Auerbach, B. A., Univ. of Penna.
9004 Horton, W. S., Jr., Pratt Inst.
9005 Squibb, W. S., Bucknell Univ.
9006 Scott, M. H., Pratt Inst.
9007 Raibourn, P. A., Univ. of Ill.
9008 Felton, H. N., Univ. of Ill.
9009 Thomson, N. M., Jr., Lewis Inst.
9010 Littlefield, M.G., Wentworth Inst.
9011 Verrall, E. H., Lewis Inst.
9012 McCabe, J. H., Mont. State Coll.
9013 Johnson, W. R., Lewis Inst.
9014 Boice, W. B., Univ. of Mich.
9015 Guptill, F. P., Univ. of Wash.
9016 Shea, H. J., Wentworth Inst.
9017 Paul, A., Jr., N. Y. Elec Sch.
9018 Lutz, H. F., Univ. of Kans.
9019 Kietzmann, C. E., Univ. of Kans.
9020 Boyer, J. M., Johns Hopkins Inst.
9021 Sassano, J. J., Cooper Union
9022 Waterman, H. E., Univ. of Idaho
9023 Harris,C.B., Rensselaer Poly.Inst.
9024 Blunk, A., Univ. of Neb.
9025 Zabe, F. J., Lewis Inst.
9026 Taylor, C. C., Colorado Coll.
9027 Anderton, T. R., N. H. Coll.
9028 Kaupman, G. A., Carnegie Inst. Tech.
9029 Griffin, H. C., Lafayette Coll.
9030 Wolf, A. C., Lewis Inst.
9031 Frisbee, J. E., N. H. State Coll.
9032 Gallup, F. D., Tri-State Coll.
9033 Halpin, C. T., Lehigh Univ.
9034 Brobst, D. R., Lehigh Univ.
9035 Shirk, W. B., Lehigh Univ.
9036 Pike, V. B., Lehigh Univ.
9037 Wenner, R. S., Lehigh Univ.
9038 Drake, E.C.,Case Sch.Applied Sci.
9039 Runkle, K. H., Iowa State Coll.
9040 Varney, N. H., Wentworth Inst.
9041 Herrle, J. N., Jr., Pratt Inst. Tech.
9042 Barnes, E. C., Univ. of Ill.
9043 Nakayama, M. Univ. of Ill.
9044 Hopkins, G. B., Univ. of Ill.
9045 Holmes, W. M., Ohio State Univ.
9046 Thomspon, S. W., Univ. of Mo.
9047 Griswold, W. F., Tri-State Coll. of Engineering
9048 Carter, P. S., Stanford Univ.
9049 Portunato, E. G., Wentworth Inst.
9050 Burleigh, A. S., N. H. Coll.
9051 Nakada, K., Univ. of Ill.
9052 MacMillan, L. C., Univ. Ill.
9053 Olsen, O. M., N. Y. Elec. Sch.
9054 Mulford, H. C., Pratt Inst.
9055 Kendig, J. E., Penna. State Coll.
9056 Given, L. E., Armour Inst.
9057 Rostock, P. G., Ohio Nor. Univ.
Total 66

PERSONAL

MR. VICTOR W. KLIESRATH, for many years Chief Engineer of the Bosch Magneto Company, has severed his connection with that concern. Mr. Kliesrath was largely instrumental in bringing the starting and lighting equipment up to the present high standard.

ARTHUR T. WARD formerly addressed c/o Braden Copper Company, Rancagua, Chile, is now residing at Bellefonte, Pennsylvania.

ACCESSIONS TO LIBRARY

This list includes books which have been presented to the library of the A. I. E. E. and the U. E. S. during the past month, not including periodicals and other exchanges.

Canada. Department of the Interior. Dominion Water Power Branch. Annual Report 1915-16. Ottawa, 1917. (Gift of Canada. Minister of the Interior.)

Los Angeles, Cal. Board of Public Utilities. Annual Report 7th, 1915-16. (Gift of Board of Public Utilities.)

Maryland. Public Service Commission. Report. 1916. Baltimore, 1917. (Gift of Public Service Commission.)

Nouvel Essai d'unification des Phénomènes naturels. By Alfred Lartigue. Paris, 1916. (Gift of Gauthier-Villars et Cie.)

Digitized by Google

On the Acoustic Efficiency of Fog-Signal Machinery. By L. V. King. (Reprinted from Journal of the Franklin Institute, March, 1917.) (Gift of author.)

Pennsylvania Glaciation first phase. By E. H. Williams, Jr. Woodstock, Vt., 1917. (Gift of author.)

Problems concerning the accident and health insurance business. An address before the Insurance Society of New York. By J. T. Stone. Jan. 16, 1917. (Gift of Insurance Society of New York.)

Steam boiler and fly wheel lines of insurance; their distinguishing features, their importance, and their growth and development. An address delivered before The Insurance Society of New York, Apr. 11, 1916, by Lyman B. Brainerd. (Gift of Insurance Society of New York.)

UNITED ENGINEERING SOCIETY

American Society of Civil Engineers. Constitution and List of Members. February, 1917. New York, 1917. (Gift of A. S. C. E.)

American Uniform Boiler Law Society. Condensed report of the American Uniform Boiler Code Congress, Washington, Dec. 4-6, 1916. Erie, Pa., 1916. (Gift of Society.)

Apportionment of railroad expenses and property values on basis of use. By A. M. Sakolski. (Reprint from the Journal of Accountancy Aug. 1916.) (Gift of author.)

Aquabar Company. Concrete tile roofing. Descriptive catalogue. Philadelphia, n.d.

——Specifications No. 11, covering the use of No. 1 compound in waterproofing mass concrete for foundation walls, subways, etc.

——No. 12. covering the use of No. 1 compound in waterproofing masonry and concrete walls and floors with cement plaster coat for foundation walls, floors, etc.

——No. 15, covering the use of No. 1 compound for waterproof cement stucco on brick and hollow tile walls. (Gift of Aquabar Company).

A Schedule of Civic Surveys. By A. C. Comey. (Bulletin No. 5, May 1916, Commonwealth of Massachusetts.) (Gift of author.)

Brachyceratops. A ceratopsian dinosaur from the two medicine formation of Montana. (U. S. Geological Survey. Professional Paper 103). Washington, 1917.

Bureau of Railway Economics. List of References on Valuation of Railways, Aug. 1, 1916. Washington, 1916. (Gift of Bureau of Railway Economics.)

Carnegie Library of Pittsburgh. Classified Catalogue. 1907-11, vols. 6-8. Pittsburgh, 1914. (Gift of Carnegie Library of Pittsburgh.)

City Manager and City Engineer-Manager. Plans of Municipal Government. By Kenyon Riddle. Abilene, Kansas, n.d. (Gift of author.)

Characteristics of Uniflow-Engine Generating Units. By E. Hagenlocher. (Reprint from Electrical World, Feb. 10, 1917). (Gift of author.)

Cost Keeping and Construction Accounting. By E. Ed. Ross. Salem, Ore., 1917. (Gift of author.)

Design and Construction of the Massachusetts Institute of Technology Buildings. By Sanford E. Thompson. (Reprinted from American Concrete Institute, July 1915.) (Gift of S. E. Thompson.)

Electric Power Club. Constitution, Executive staff, member companies. By-laws. Ed. 10, 1917. Chicago, 1917. (Gift of Club.)

Engineers Club of Boston. By-laws, officers and list of members. Apr. 2, 1917. (Gift of Club.)

Experimental Engineering and Manual for Testing. By R. C. Carpenter. Ed. 6. New York John Wiley & Sons, 1907. (Gift of Publisher.)

Federal Valuation of Common Carriers. By J. P. Nelson. n. p. 1916. (Gift of Clemens Herschel.)

Federal Valuation of the Railroads in the United States. Statement prepared by H. C. Phillips, general Secretary, of the developments in connection with Federal Valuation, as of April 20, 1917. (Gift of Clemens Herschel.)

Federal Valuation of the Railroads in the United States. Circular communication to the chairmen of valuation committees, in reference to the supplement to Interstate Commerce Commission valuation order No. 7—schedules of land. April 10, 1917. (Gift of Clemens Herschel.)

Grouping of Public Buildings and Gardens, with adjoining water front, excursion docks and union station for the City of Buffalo. Buffalo, n.d. (Gift of George Cary.)

Interstate Commerce Commission. Hearings before, on March 19-24, 26-31, 1917. (Gift of Clemens Herschel.)

Massachusetts. Department of Weights and Measures. Measurements for the Household. Ed. 2, Jan. 1917. Boston, 1917. (Gift of Department of Weights & Measures)

McClintic Marshall Construction Company. Report on the claim against the Isthmian Canal Commission, submitted to the Senate pursuant to act of Congress of June 24, 1914. By G. W. Goethals. Washington, 1916. (Gift of Panama Canal Press.)

New York State Engineer and Surveyor. Annual Report vol. I, 1916. Albany, 1917. (Gift of State Engineer & Surveyor.)

Progress of Federal Valuation. By A. M. Sakolski. (Gift of author.)

Public Office. From a Civil Service and Business Point of View. By John J. Hopper. Albany, 1917. (Gift of Register of New York County.)

Pueblo, Colo. City Controller. Annual Statement, 1916. Pueblo, 1916. (Gift of City Controller.)

Railway Statistics of the United States of America, 1916, compared with the official reports

Digitized by Google

for 1915 and recent statistics of foreign railways. By Salson Thompson. Chicago,1917. (Gift of author.)

Rules for docking vessels in dry docks belonging to the Panama Canal. Mount Hope, 1916. (Gift of Panama Canal Press.)

Some Comments on Federal Valuation of Common Carriers. By J. P. Nelson. (Spoken before the Richmond Railroad Club, Feb. 12, 1917). (Gift of Clemens Herschel.)

Trus-Con Laboratories. Architects specification hand book of waterproofing, dampproofing, technical paint, etc. Detroit, n.d. (Gift of Trus-Con Laboratories.)

Trussed Concrete Steel Company. Kahn Road Book devoted to concrete roads and pavements. Youngstown, 1916. (Gift of Trussed Concrete Steel Co.)

Valuation of Railroad Right-of-way. By A. M. Sakolski. (Reprinted from American Economic Review, June, 1916.) (Gift of author.)

Wallace & Tiernan Company, Inc. Protecting the Water Supply of Greater New York. New York, 1916.

——The cost Hypochlorite vs. Liquid chlorine New York, 1916. (Gift of Company.)

GIFT OF CARLETON GREENE

Collins, John. Explorations in Central America (From Proceedings Royal Geographical Society of London, 1867).

Couvreux, A. & Hersent, H. Les nouvelles installations maritimes du Port d'Anvers. Paris, 1879, 1880.

De Rouchmont, Quintette. Notice sur le port du Havre. Paris, 1875.

New York Board of Water Commissioners. Brooklyn Water Works and Sewers. A descriptive memoir. N. Y., 1867.

Reynaud, Léonce Memoir upon the illumination and beaconage of the coasts of France. Wash., 1876.

U. S. Department of State. Reports upon the survey of the boundary between the territory of the United States and the possessions of Great Britain from the Lake of the Woods to the Summit of the Rocky Mountains. Wash., 1878.

——Joint maps of the northern boundary of the United States from the Lake of the Woods to the Summit of the Rocky Mountains.

Williams, J. J. Isthmus of Tehuantepec, N. Y., 1852.

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-243. Wanted: Young technically trained men to take up engineering work in connection with telephone transmission and equipment problems. State age, educational advantage, experience, present occupation and salary expected.

V-244. Opportunities for recent technical graduates in laboratory development work along telegraphic signalling lines. Good future for the right men. Give particulars of training and experience, if any, and salary desired.

V-245. Large holding company wishes to take on several young technical graduates for drafting in connection with power plant and substation layouts. Men preferred with several years' experience, particularly along electrical lines, who are qualified to follow up the plans with execution of the work. Unlimited opportunity for advancement. Advise in detail experience and salary required.

V-246. Wanted: Electrical Draftsmen for high-tension station and substation design; excellent working conditions with good future. Address P. O. Box 1902, Philadelphia, Pa.

MEN AVAILABLE

763. Assoc. A. I. E. E., desires position as plant engineer. Knowledge of general factory planning, arrangement of machine tools, motor applica-

Digitized by Google

tions, piping and powerhouse work. Thoroughly conversant with concrete foundation construction, carpentry, bricklaying and rigging.

764. Man with broad sales and engineering experience will consider and accept a proposition as manager or in the above capacity. An appointment would be preferred to correspondence as results can be shown.

765. Manager or Superintendent for industrial or power company, wants better position. Now in responsible charge of design of large chemical plant and other consulting work. Familiar with modern business and efficiency methods and engineering of chemical, electrical, steam and hydraulic plants. Present salary $3,000.

766. Superintendent of construction and operation; several years' operating large hydroelectric plants and with manufacturing experience, desires position in United States or abroad.

767. Fuel is the big item. Engineer, who is saving present employers $6,000 per year in their boiler room, is seeking position as chief engineer of larger plant, or as superintendent of light and power property.

768. Electrical technical graduate, at present in the testing department of General Electric Co., desires position with a growing electric company. Construction work preferred, although any department with chance for advancement will be acceptable.

769. Electrical Engineer, technical graduate. Three years' operating, test, general shop preparation and erecting engineer, large manufacturing company; three years in responsible positions over operation of steam and hydroelectric stations and high-tension transmission system. Engaged outside of States and available for change of position. Public utility field preferred.

770. Electrical engineering graduate 1915, age 25, married; desires position with either a consulting engineer or manufacturing company in the vicinity of Chicago or farther west. Since graduation has had one year of operating and construction work and for the past year has been employed in the design of large generating and substations.

771. American, 34, technically trained, married; returning from South America June 1, wishes position as construction superintendent or as electrical engineer and master mechanic of large industrial organization. Thirteen years' experience covering all branches of electrical work and layout and upkeep of manufacturing machinery. Will report anywhere for personal interview.

772. Thoroughly competent steam efficiency engineer. Technical graduate, with operating experience in large generating stations. Wishes position as assistant to superintendent of operation. Pacific Coast only.

773. Electrical and Mechanical Engineer of fifteen years' successful practical experience; can design, supervise or organize original or new work, where initiative, tact and perseverance are required. Temperamentally qualified to adapt self to various personnel within or without an organization. At present employed, but desires new connections where there is ample opportunity to produce results.

774. Engineer-Executive. I am 32, and married. I am employed. I am a university graduate in electrical engineering (1908), and I am enrolled in the "Modern Business Course" with the Alexander Hamilton Institute. I have had eight years' engineering, manufacturing and executive experience. I am available on four weeks' notice. Minimum salary—$2500 per year.

775. Transformer Engineer. Technical graduate, with four years' experience with General Electric Co., in testing and transformer engineering department, and two years in charge of transformer design with smaller company, desires a change. Familiar with latest types; competent and resourceful, and strictly reliable. Age 31 and married.

776. Graduate in electrical engineering, correspondence school course. Eight years in charge electrical construction for engineering firm; two years operating in substation; two years' power plant operation. Desires position where past experience may be of service.

777. Competent Engineer, executive ability, many years' experience with telephone, telegraph, wireless, electric lighting and power work, desires position with good concern in the Middle West.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917) **SECRETARY.**
GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY.
RALPH W. POPE

LIBRARIAN.
W. P. CUTTER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to June 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.
N. A. Carle, George A. Hamilton,
John H. Finney, William McClellan,
Bancroft Gherardi, J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.
N. A. Carle, Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.
Frederick Bedell, F. W. Peek, Jr.
Philander Betts, F. L. Rhodes,
H. H. Clark, D. W. Roper,
J. G. De Remer, Harris J. Ryan,
H. A. Hornor, T. H. Schoepf
Edward P. Hyde, Charles P. Steinmetz,
L. E. Imlay, N. W. Storer,
E. H. Martindale, Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
Frederick Bedell, L. T. Robinson,
M. G. Lloyd, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 W. 23rd Street, New York.
E. B. Katte, W. I. Slichter,
F. L. Rhodes, Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
J. G. De Remer, A. M. Schoen,
Paul M. Lincoln, J. H. Tracy,
and the chairmen of all Institute Sections, *ex-officio*.

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.
G. M. Baker, W. G. Chace,
S. H. Blake, H. W. Flashman,
E. H. Martindale.
and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.
E. A. Carolan, A. M. Hunt,
John J. Carty, William McClellan,
Fredk. Darlington, H. H. Porter,
Gano Dunn, C. S. Ruffner,
John B. Fiske, A. M. Schoen,
L. B. Stillwell,

COMMITTEE ON DEVELOPMENT OF WATER POWER

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.
F. O. Blackwell, Nicholas S. Hill, Jr.,
Francis Blossom, E. A. Lof,
Gano Dunn, W. V. N. Powelson,
L. B. Stillwell.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, H. M. Hobart,
Frederick Bedell, H. D. James,
Joseph Bijur, P. Junkersfeld,
L. F. Blume, A. E. Kennelly,
James Burke, G. L. Knight,
G. A. Burnham, A. S. McAllister,
N. A. Carle, W. M. McConahey,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
W. A. Del Mar, C. E. Skinner,
E. J. Edwards, A. J. Slade,
H. W. Fisher, N. W. Storer,
W. S. Gorsuch, R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, M. I. Pupin,
B. A. Behrend, E. B. Rosa,
Louis Bell, Charles F. Scott,
James Burke, Clayton H. Sharp,
John J. Carty, Samuel Sheldon,
Gano Dunn, C. E. Skinner,
H. M. Hobart, Charles P. Steinmetz,
John W. Lieb, Elihu Thomson,
R. B. Owens, Philip Torchio.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.
Bion J. Arnold, Charles A. Terry,
John F. Kelly, B. F. Wood,

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.
A. E. Kennelly, Chairman, Robert T. Lozier,
S. G. McMeen.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.
Charles F. Brush, N. W. Storer,
C. C. Chesney.

Term expires July 31, 1920.
Carl Hering, Harris J. Ryan.

Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.
B. A. Behrend, Paul M. Lincoln,
William McClellan.

Term expires July 31, 1918.
C. A. Adams, Harold Pender,
C. E. Skinner.

Ex-Officio.
H. W. Buck, President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to June 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
55 Liberty Street, New York.

J. M. Drabelle,	S. A. Moss,
C. C. Egbert,	R. J. S. Pigott,
W. S. Gorsuch,	Cecil Poole,
John Harisberger,	E. F. Scattergood,
A. H. Kruesi,	P. A. Scheffler,
Paul M. Lincoln,	W. R. Thompson,
Wynn Meredith,	Philip Torchio,
I. E. Moultrop,	H. L. Wallau,

B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,	P. M. Lincoln,
M. T. Crawford,	W. E. Mitchell,
E. E. F. Creighton,	G. J. Newton,
H. H. Dewey,	L. C. Nicholson,
P. M. Downing,	W. D. Peaslee,
H. W. Fisher,	Stefaan Piek,
F. A. Gaby,	C. S. Ruffner,
W. T. Goddard,	H. J. Ryan,
O. A. Havill,	F. D. Sampson,
R. F. Hayward,	H. E. Shedd,
J. P. Jollyman,	Julian C. Smith,

P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman.
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,	P. J. Kearny,
A. H. Babcock,	William McClellan,
Reinier Beeuwkes,	John Murphy,
E. J. Blair,	W. B. Potter,
L. P. Crecelius,	E. D. Priest,
J. V. B. Duer,	Charles H. Quinn,
George Gibbs,	Clarence Renshaw,
W. J. Harvie,	A. S. Richey,
Hugh Hazelton,	Charles F. Scott,
E. B. Katte,	John B. Taylor,

H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,	G. A. Johnstone,
J. H. Davis,	C. A. Kelsey,
James Dixon,	C. L. Kennedy,
A. M. Dudley,	Charles D. Knight,
Herbert D. Dwight,	A. H. Lawton,
F. W. Ells,	A. M. MacCutcheon,
J. E. Fries,	A. G. Pierce,
F. R. Fishback,	James M. Smith,
R. H. Goodwillie,	H. Weichsel,
A. L. Hadley,	J. B. Wiard,

R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,	Richard C. Powell,
C. E. Clewell,	E. B. Rosa,
J. R. Cravath,	W. D'A. Ryan,
T. S. Perkins,	Clayton H. Sharp,

W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,	A. H. Kruesi,
W. H. Blood, Jr.	William McClellan,
Fred A. Bryan,	Norman C. McPherson,
C. L. Cory,	Allard Smith,
Harry Clifford Eddy,	W. G. Vincent,
W. B. Jackson,	George W. Wittemore,

Clifton. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
72 W. Adams St., Chicago, Ill.

L. L. Elden,	A. A. Meyer,
G. Faccioli,	L. C. Nicholson,
V. E. Goodwin,	N. L. Pollard,
E. M. Hewlett,	S. D. Sprong,
Paul M. Lincoln,	Philip Torchio,

H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,	F. G. Liljenroth,
F. A. J. Fitzgerald,	Eugene F. Roeber,
A. F. Ganz,	J. A. Seede,
F. A. Lidbury,	R. Tencher.

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,	E. B. Rosa,
A. C. Crehore,	Harris J. Ryan,
G. Faccioli,	Clayton H. Sharp,
C. L. Fortescue,	C. P. Steinmetz,
W. S. Franklin,	P. H. Thomas,
A. E. Kennelly,	J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
195 Broadway, New York.

E. F. W. Alexanderson,	Kempster B. Miller,
R. E. Chetwood,	H. Mouradian,
M. M. Davis,	W. O. Pennell,
C. L. Fortescue,	Allard Smith,
H. M. Friendly,	John S. Stone,
F. B. Jewett,	John B. Taylor,
S. M. Kintner,	J. L. Wayne, 3rd.
Wm. Maver, Jr.,	G. M. Yorke,

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.
D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,	Guy Hill,
M. W. Day,	O. P. Loomis,
G. E. Edgar,	G. A. Pierce, Jr.,
W. L. R. Emmet,	H. M. Southgate,
W. R. Furlong,	E. A. Sperry,
H. L. Hibbard,	Wilfred Sykes,

F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,	L. C. Ilsley,
Frank H. Armstrong,	R. L. Kingsland,
Graham Bright,	Charles Legrand,
W. A. Chandler,	Charles M. Means,
F. J. Duffy,	K. A. Pauly,

H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,	A. G. Pierce,
F. B. Crosby,	J. C. Reed,
E. Friedlaender,	R. Tencher,
E. S. Jeffries,	Brent Wiley,
D. M. Petty,	R. B. Williamson

J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman.
Columbia University, New York.

Alexander Gray,	William McClellan,
E. J. Henkhe,	Chester W. Rice,
E. A. Loew,	C. E. Skinner

R. D. Thomson.

Digitized by Google

SPECIAL COMMITTEES.

Revised to June 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
F. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman,
Massachusetts Institute of Technology, Boston, Mass.
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. F. Scott.

COMMITTEE ON NATIONAL DEFENSE

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.

F. C. Bates, Secretary,
30 Church Street, New York,

B. J. Arnold, D. C. Jackson,
A. H. Babcock, John W. Lieb,
Philander Betts, P. M. Lincoln,
H. W. Buck, Ralph D. Mershon,
J. H. Cuntz, A. M. Schoen,
J.J. Carty J. Franklin Stevens.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S. McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

Ralph D. Mershon, Paul M. Lincoln,
C. O. Mailloux, John J. Carty.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

Harold Pender, Edward D. Adams,
W. I. Slichter, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON CONFERENCE COMMITTEE OF NATIONAL ENGINEERING SOCIETIES.

Calvert Townley, William McClellan,
John J. Carty.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly,

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand,
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.
A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France.
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa.

ENGINEERING SECTION OF THE COMMITTEE ON SCIENCE AND RESEARCH, ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

Digitized by Google

LIST OF SECTIONS

Revised to June 1, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg.Atlanta,Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St., Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, 433 West Forest Ave., Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Union Tel. Co. Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	Gordon Campbell	M. B. Carroll, G. E. Co., West Lynn, Mass
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7. '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, 1220 Spalding Bldg., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	J. W. Morrison, Rochester Telephone Co., Rochester N. Y.
St. Louis.....Jan. 14, '03	A.McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	E. T. J. Brandon	Wills Maclachlan, 910 Excelsior Life Building, Toronto, Ont.
Urbana.....Nov. 25, '02	I. W. Fisk	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col..Jan. 10, '08	R. H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	R. W. Davis	Clark Davis, University of Kansas, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Samuel McC.Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute,Chicago.
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech.....Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of...May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr., and Mech. Arts.Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of.Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University, N. D.
Norwich University....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ.....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University..Dec. 20, '02	H. D. Bender	L. W. Birch, 138 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of....Oct. 11, '12	H. M. Richards	R. E. Heffner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly,	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst..Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of...Dec. 13, '07	D. M. Alexander	C. W. Cutler, 702 California St., Pullman, Wash.
Washington Univ.....Feb. 6, '04	Charles A. Lieber	R. W. MacDonald, Washington University, St. Louis, Mo.
Washington, Univ. of..Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ.....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst...Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 59

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI JULY, 1917 Number 7

SPECIAL MEETING OF A. I. E. E., NEW YORK, JUNE 27-28, 1917

The special New York meeting of the American Institute of Electrical Engineers for the presentation and discussion of papers originally scheduled for the Annual Convention and the April Schenectady meeting was held on June 27-28, 1917, at the Institute headquarters, 33 West 39th Street, New York, N. Y.

Wednesday Morning

The first session was called to order at 10:30 a. m. Wednesday by President Buck. This session was devoted to the presentation of four papers on the subject of High-Tension Cables. Mr. John L. Harper abstracted his paper on "Problems in Operation and Maintenance of Underground Cables." Mr. D. W. Roper abstracted his paper on "High-Tension Cable Joints." Mr. A. F. Bang abstracted a paper by himself and Mr. H. C. Louis on "The Influence of Dielectric Losses on the Rating of High-Tension Underground Cables" and Mr. G. B. Shanklin abstracted a paper by himself and Mr. W. S. Clark on "Insulation Characteristics of High-Voltage Cables."

Before proceeding with the discussion of these papers President Buck introduced Capt. Gustave Paul Cappart of the French army, an electrical engineer. Capt. Cappart conveyed the greetings of the French electrical engineers and in describing present conditions in France remarked: "We used to say time is money; now we say time is blood. It is now for you to make the world safe for democracy by victory."

Discussion of the papers was then called for and participated in by the following men: W. I. Middleton, P. Torchio, H. R. Woodrow, J. B. Whitehead, D. W. Roper, A. F. Bang, C. A. Adams, H. C. Louis, L. T. Robinson, W. S. Clark, D. DuBois, E. E. Meyer, J. L. Harper, C. N. Rakestraw and C. W. Davis.

Wednesday Afternoon

The second session was called to order at 2.15 p. m. with Vice-President L. T. Robinson presiding. The subject of this session was High-Tension Insulators and three papers were presented as follows: "The Insulator Situation," by W. D. Peaslee, which was abstracted by H. R. Woodrow, "Expansion Effects as a Cause of Deterioration in Suspension Type Insulators," by J. A. Brundige, abstracted by the author, and "Present Practise in Design and Manufacture of High-Tension Insulators," by A. O. Austin, also abstracted by the author. These papers brought forth discussion by the following men: H. R. Woodrow, J. C. Clark, E. E. F. Creighton, E. M. Hewlett, P. Torchio, P. Thomas, J. B. Taylor, C. F. Harding, J. T. Baron, J. A. Brundige, A. O. Austin, and a letter from H. J. Ryan read by J. C. Clark.

Wednesday Evening

President Buck called the meeting to order at 8:30 p. m. and delivered the

Digitized by Google

President's Annual Address. He dealt with the growing tendency toward co-operation among engineers, wider service in behalf of the public, and the relation of the engineering profession to pure science. This address will be published in full in a future issue of the PROCEEDINGS.

The President then presented President-Elect E. W. Rice, Jr., who after expressing his deep appreciation of the honor conferred upon him made a brief address pointing out the part this country must play in bringing the war to a successful close, and how that result can be attained only through unanimous individual co-operation, as war has become a gigantic business proposition that can be handled only through an immense and intensely autocratic business corporation. President-Elect Rice's remarks will be published in a future issue of the PROCEEDINGS.

After the close of Mr. Rice's address Mr. C. O. Mailloux made an appeal at the request of Captain Cappart, for volunteers familiar with electrical construction work in various branches, to go to France and help in the enormous work of reconstruction. A special contingent of electrical men will probably be organized for this service the details of which will probably be brought formally to the attention of electrical men in the near future.

The chairmen of the various technical committees then made their annual reports, which will be found elsewhere in this issue.

THURSDAY MORNING

The third technial session was presided over by Vice-President C. A. Adams who called the meeting to order at 10:30 a. m. This session was devoted to the subject of Mining and two papers were presented as follows: "Forms of Power Best Suited for Various Loads Encountered in the Operation of Bituminous Coal Mines" abstracted by the author R. L. Kingsland, and "Test of a Large Mine Hoist," by R. S. Sage, also abstracted by the author. The following men took part in the discussion: A. S. McAllister, R. L. Kingsland, K. A. Pauly, H. C. Clark, E. H. Martindale and R. S. Sage. Several written discussions, read by H. C. Clark, were furnished by the following men: C. M. Means, H. B. Kiser, G. Bright, F. J. Duffy, L. C. Ilsley.

THURSDAY AFTERNOON

This session called to order by President Buck at 2 p. m. was devoted to two subjects, Water Power and Heating of Electrical Machinery. Under the first subject the paper "Economical Combination of Water Power and Steam Plants and a Convenient Method of Solution" by H. S. Putnam was abstracted by the author and discussed by the following: C. T. Hutchinson, H. R. Summerhayes and H. S. Putnam.

The second paper "Cooling of Oil-Immersed Transformer Windings After Shut-Down" by V. M. Montsinger was abstracted by the author. The following men took part in the discussion: A. S. McAllister, V. M. Montsinger, F. F. Brand, L. T. Robinson, L. F. Blume, and W. C. Smith.

DIRECTORS' MEETING JUNE 28, 1917.

The regular monthly meeting of the Board of Directors of the Institute originally scheduled for June 27, was held at Institute headquarters, New York, June 28, immediately after the adjournment of the last technical session referred to above.

There were present; President H. W. Buck, New York; Vice-Presidents C. A. Adams, Cambridge, Mass., J. Franklin Stevens, Philadelphia, Pa., William McClellan, New York, B. A. Behrend, Boston, Mass., L. T. Robinson, Schenectady, N. Y.; Managers Frederick Bedell, Ithaca, N. Y., A. S. McAllister, New York, F. B. Jewett, New York. John B. Taylor, Schenectady, N. Y., C. E. Skinner, Pittsburgh, Pa., N. A, Carle, Newark, N. J., Charles Robbins, Pittsburgh, Pa., and Secretary F. L. Hutchinson, New York.

Digitized by Google

The action of the Finance Committee in approving monthly bills amounting to $9,588.03, was ratified.

The report of the Board of Examiners of meetings held on June 15th and June 21st was read and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners the following action was taken on pending applications. Sixty-one students were ordered enrolled, 98 applicants were elected to the grade of Associate, 11 to the grade of Member, and 1 to the grade of Fellow, 6 applicants were transferred to the grade of Member, and 1 to the grade of Fellow, and 3 applicants were re-elected to the grade of Associate.

On recommendation of the Standards Committee the Board approved a supplement to the Standardization Rules embodying the additions and modifications to the Rules as recommended by the Committee during the past year. This supplement will be published in August issue of the PROCEEDINGS.

A considerable amount of other business was transacted, reference to which will be found in future issues of the PROCEEDINGS.

The members of the Board met again at a subscription dinner at the Harvard Club, Thursday evening. President-Elect Rice and former Vice-President Farley Osgood were also present. President Buck was presented with a Past-President's badge, Mr. Farley Osgood making the presentation speech, and all present expressed their pleasure at having served upon the Board during President Buck's administration. In responding President Buck expressed his appreciation of the hearty and effective cooperation of the members of the Board during the year, and the hope that he would continue to be associated with all of them in connection with Institute work in the future. Vice-Presidents Stevens, Adams and McClellan, whose terms as members of the Board will expire July 31st, expressed similar sentiments.

There was an interesting discussion by all in attendance, this result being brought about largely by the effective work of Vice-President Robinson in his capacity as toastmaster.

DINNER TO PRESIDENT-ELECT RICE

A dinner in honor of President-Elect E. W. Rice, Jr., was given by Mr. David B. Rushmore, at the Engineers' Club, New York, on Tuesday evening, June 26th. The guests included 12 Past-Presidents of the Institute, the Presidents of the four principal national engineering societies and of the United Engineering Society, and a few others prominent in engineering and scientific work.

The occasion was exceedingly enjoyable to all present, and afforded an opportunity for an interesting and profitable exchange of views upon matters of interest to the engineering profession.

All present felicitated Mr. Rice upon his election as President of the Institute and pledged their hearty cooperation during his coming administration.

GREETINGS FROM THE INSTITUTION OF ELECTRICAL ENGINEERS

The following cablegram was received by the Institute on May 21st from The Institution of Electrical Engineers of Great Britain:

"The President and Council and the members of The Institution of Electrical Engineers send hearty greetings to their brothers of the American Institute of Electrical Engineers and hereby express to them their sincere appreciation of the entry of the great American nation into the war on behalf of civilization and its ideals and of the deep significance of their action for the cause of the British Empire and its allies."

President H. W. Buck cabled in reply, on behalf of the Institute, as follows:

"The American Institute of Electrical Engineers deeply appreciates your message. We hope that the Electrical Engineers of Great Britain and of America, working together in close cooperation, can bring to a satisfactory conclusion the many electrical problems of the war."

Digitized by Google

NATIONAL COMMITTEE ON GAS AND ELECTRIC SERVICE

Some months ago the Committee of the American Gas Institute to Cooperate with the Government in regard to the Military Needs of the Nation and the Committee of the National Electric Light Association on War Conditions, at a joint conference held in New York City decided to organize a National Committee which would secure to the United States Government the most effective co-operation in the conduct of the war from the gas and electric light and power industries. The National Committee on Gas and Electric Service was thereupon organized with a membership of representative men from these two industries and the related natural gas industry. The committee, as constituted, is as follows: Walter R. Addicks, Vice President, Consolidated Gas Co. of New York, New York, N. Y.; Philip P. Barton, Vice President, Niagara Falls Power Company, Niagara Falls, N. Y.; John A. Britton, Vice President, Pacific Gas and Electric Company, San Francisco, Cal.; Alex. Dow, President, Detroit Edison Company, Detroit, Michigan; Charles L. Edgar, President, Edison Electric Illg. Co. of Boston, Boston, Mass.; A. E. Forstall, President, American Gas Institute, New York, N. Y.; Joseph F. Guffey, President, Natural Gas Association of America, Pittsburgh, Pa.; Samuel Insull, President, Commonwealth Edison Company, Chicago, Ill.; D. C. Jackson, Prof. of Electrical Engineering, Massachusetts Institute of Technology, Boston, Mass.; Joseph B. McCall, President, The Philadelphia Electric Company, Philadelphia, Pa.; Capt. William E. McKay, Vice President, New England Gas and Coke Company, Boston, Mass.; Herbert A. Wagner, President, Consolidated Gas Electric Lt. & Pr. Co., Baltimore, Md.; S. S. Wyer, Consulting Engineer, Natural Gas Industry, Columbus, Ohio; John W. Lieb, Vice President, The New York Edison Company, New York N. Y., (Chairman of Committee); William H. Gartley, Vice President, Equitable Illg. Gas Lt. Co. of Philadelphia, Philadelphia, Pa., (Vice Chairman of Committee); George W. Elliott, Washington, D. C. (Secretary of Committee).

The committee is recognized by the Advisory Commission of the Council of National Defense as one of its Advisory Comittees, and it has established an official headquarters in the Munsey Building, Washington, D. C., where it has placed itself at the service of the Government for any assistance it may be able to render in behalf of the public utility industries it represents. It is prepared to act as a vehicle of communication between the various instrumentalities organized by the Government for the conduct of the war and the gas companies producing and distributing artificial and natural gas and the electric light and power companies furnishing electric service, in all matters relating to the national defense. It proposes to promptly place at the disposal of the government any data or information which it may require as to the facilities in men or service which they may have available, ensure the continuous operation of their plants so as to enable the munition plants, navy yards and manufacturing establishments, through continuous and uninterrupted service, to maintain their maximum output, and it will endeavor to provide the Government with the necessary quantity of the essential by-products they can make available for the production of high explosives and of ammunition.

One of the most essential requirements in the coordination of the industrial resources of the country for the successful conduct of the war is to provide a regular and adequate supply of fuel to the important utilities engaged in enterprises through which they render service to the Government and to the public. To facilitate solving the many problems affecting the continuous supply of fuel to operate their plants, the National Coal Board has

Digitized by Google

been pleased to appoint Mr. George W. Elliott, Secretary of the Committee, to membership on the Coal Committee. A questionnaire is now being prepared which will, within the next few days, be forwarded to every gas and electric light and power company in the country, asking them to send a statement of the various kinds and quantities of fuel each uses per annum for its various purposes, the water or rail connections over which they are received, together with a monthly statement of fuel contracted for, received and consumed. This will enable the committee to give prompt information to the authorities of fuel shortage in any particular locality, with the transportation lines involved, loading and unloading delays, car shortages, routing and trans-shipment difficulties, etc.

The committee has been in consultation with the authorities on matters affecting the service which the employees of the companies may render to the Government and in regard to various questions connected with selective registration, conscription exemptions and provision for the dependents of employees who may be called upon to render military service. The furnishing of heat, light and power service to the troop cantonments for the mobilization of the military forces located in different parts of the country is now being considered and information is being collected as to how these agencies may be made available to the camps in the shortest possible time from the nearest points of supply.

It is believed that this National Committee on Gas and Electric Service can be of great assistance to the Government in these several directions and that it will cover a broad field of useful and patriotic service, bringing to bear on the successful conduct of the war, from the standpoint of efficient industrial mobilization, the vast resources of men and facilities which the utility companies of the country have at their command and through which they are now efficiently serving the public and which they desire to make available to the nation to the greatest practicable extent.

PRESENTATION OF THE JOHN FRITZ MEDAL TO HENRY MARION HOWE

On the evening of May 10, 1917 the presentation ceremonies of the John Fritz Medal Award took place in the Auditorium of the United Engineering Building, 29 West 39th Street, New York, at 8:30 p.m.

Dr. Henry Marion Howe, the recipient, was awarded this signal honor for his "investigations in metallurgy, especially in the metallography of iron and steel."

Professor Albert Sauveur, Chairman of the Board at the time the award was made, presided. He spoke of the broadening and elevating influence the establishment of this award has had upon the engineering profession and called the honor roll of those who have received the medal.

Dr. Rossiter W. Raymond, Secretary Emeritus of the American Institute of Mining Engineers, the next speaker, called attention to the enormous labor and care involved in sorting and correlating data originating from the discovery or development of a new science. In a brief biographical and bibliographical statement Dr. Raymond showed just what Dr. Howe had accomplished for the new science of metallography. He then presented Dr. Ira N. Hollis. Dr. Hollis dwelt on the moral aspect of science, especially on that side of it which promotes practical application, as Mr. Howe's career well illustrates the motive that must always lie behind the engineers work, if the profession is to live and to be found worthy.

Prof. Sauveur then made the presentation of the medal to Dr. Howe alluding to what a happy coincidence it was that such a staunch friend of the Entente Allies should receive this honor at the time of the reception of the French mission.

Dr. Howe expressed his deep appre-

Digitized by Google

ciation of the honor accorded him. He then gave a brief outline of the fundamental causes of the world war and pointed to the absolute necessity that democracy must triumph if we wish to prevent future wars where the scientific destructive powers evolved are sure to be enormously enhanced.

THIRD NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES

During the week of September 24th, 1917 the third National Exposition of Chemical Industries will be held at the Grand Central Palace, New York. Preparations for the exhibit are now in progress and the exposition promises to be still more interesting and comprehensive than last year's affair.

PAST SECTION MEETINGS

Boston.—May 8, 1917, Engineers Club. Subject; "What is Being Done." Speakers: Major H. G. Chase and Mr. Charles R. Gow. Election of officers for the coming year as follows—chairman, Harry M. Hope; vice-chairman, L. E. Abbott; secretary and treasurer, I. M. Cushing. Attendance 75.

Chicago.—May 28, 1917, Western Society of Engineers Rooms. Paper: "Electric Waves" by William S. Franklin. Election of officers as follows—chairman, William J. Crumpton, secretary, C. A. Keller. Attendance 138.

Cleveland.—May 21, 1917, Electrical League Rooms. Illustrated address on "Acoustical Engineering" by Mr. John B. Taylor. Election of officers as follows—chairman, C. M. Rakestraw; secretary, C. S. Ripley.

Denver.—May 21, 1917, Denver Athletic Club. Address by Mr. L. L. Quigley on "Electric Hoisting". Attendance 78.

Detroit-Ann Arbor.—May 18, 1917, Ann Arbor. Paper: "Electrical Conductors and Insulators" by W. F. Colby. Attendance 30.

Fort Wayne.—May 23, 1917, Majestic Theatre. Lecture by Dr. C. P. Steinmetz on "The Effect of the European War on American Industries". Attendance 1600.

June 14, 1917, Commercial Club. Reports of committees on work accomplished during year. Election of officers as follows—chairman, J. J. Kline; secretary, R. B. Roberts. Attendance 16.

Indianapolis-Lafayette.—May 18, 1917, Indianapolis. Paper: "Storage Batteries; Their Application and Construction" by C. A. Jaqua. Attendance 40.

Ithaca.—May 11, 1917, Franklin Hall. Papers: (1) "Electrification of Steam Railroads—General Estimates and Data" by S. B. Fortenbaugh; (2) "Do Lines of Force Move" by E. H. Kennard. Attendance 41.

May 18, 1917, Syracuse. Paper: "The Owen Magnetic Car and the Entz Transmission System" by Walter S. Goll. Demonstration of a model which imitates quantitatively the performance of an Entz motor-generator set, by Prof. V. Karapetoff. Attendance 50.

Madison.—June 4, 1917, University of Wisconsin. Subject: "Wave Form of Electrical Machinery." Speakers: Mr. G. H. Gray, Mr. C. C. Dodge, and Prof. J. R. Price. Attendance 32.

Pittsburgh.—May 8, 1917, Union Arcade Building. Addresses by Lieut. Col. Jadwin and Major Fay on "The Engineer in War-Time". Attendance 250.

June 12, 1917, Union Arcade Building. Papers: (1) "Selective Conscription and What It Means" by L. M. Johnston; (2) "Some Naval Engineering Problems" by Commander M. E. Reed. Attendance 100.

Portland.—Multnomah Hotel. Papers: (1) "Description of Chart to Determine Proper Sag for Stringing Aerial Wires" by H. H. Schoolfield; (2) "Determination of Efficient Ground Connections for Distribution Systems" by W. C. Heston; (3) "Reclamation Load on North Coast Power Company's Lines" by R. M. Boykin. Attendance 35.

Digitized by Google

Rochester.—May 25, 1917. Motion picture "King of the Rails". Election of officers as follows—chairman, Frank C. Taylor; secretary-treasurer, J. W. Morrison. Members of executive committee Messrs. A. S. McDowell, G. M. Cameron, H. E. Lawrence and G. A. Scoville. Attendance 75.

San Francisco.—May 24, 1917, Elk's Hall. Paper: "Modern Development in Street Lighting" by F. C. Piatt. Attendance 35.

Schenectady.—April 20, 1917, Edison Club Hall. Address by Dr. C. R. Mann on "A New Basis for Engineering Education". Attendance 250.

May 4, 1917, Edison Club Hall. Illustrated lecture by Mr. J. B. Taylor on "Acoustical Engineering and a Review of the Characteristics of Noise, Speech and Musical Sound". Attendance 200.

May 25, 1917, Edison Club Hall. Address on "Personal Experiences in the European War" by A. G. Empey. Attendance 500.

Seattle.—May 15, 1917, Arctic Building. Paper: "Transmission Line Design" by F. K. Kirsten. Attendance 27.

Spokane.—May 18, 1917, Spokane Hotel. Address by Prof. H. V.Carpenter on "Engineering Education". Election of officers as follows—chairman, Chas. A. Lund; vice-chairman, George Nixon; secretary-treasurer, J. E. E. Royer; executive committee, R. S. Daniels, J. W. Hungate and George Harding. Attendance 51.

Toledo.—June 8, 1917, Toledo Commerce Club. Addresses as follows—(1) "District Heating and Electric Generation" by A. C. Rogers; (2) "The Lighting of the Statute of Liberty" by W. E. Richards. Attendance 26.

Toronto.—April 4, 1917, Engineers Club. Subject: "Electric Furnaces." Speakers: Mr. J. T. Burt-Gerrans and A. Turnbull. Attendance 110.

Utah.—May 28, 1917, Commercial Club. Election of officers as follows—chairman, A. S. Peters; secretary-treasurer, H. T. Plumb; executive committee, S. R. Inch, J. C. Jones, C. P. Kahler and J. F. Merrill.

Washington.—May 9, 1917, Capital Traction Company's Office. Motion picture "King of the Rails". Election of officers. Attendance 51.

PAST BRANCH MEETINGS

University of Arkansas.—May 15, 1917. Address by Prof. Baender on "The Use, Construction and Care of Ball Bearings". Election of officers as follows—president, W. L. Teague; secretary-treasurer, J. C. Douthit. Attendance 21.

Armour Institute.—May 18, 1917, Electrical Engineering Lecture Room. Election of officers as follows—chairman, E. A. Moore, Jr.; treasurer, H. H. Shotwell; secretary, A. A. Hofgren. Attendance 26.

University of Colorado.—May 17, 1917, Engineering Building. Address by Prof. Evans on "The Future of Electrical Engineering in the United States". Election of officers as follows—chairman, Robert Newman; vice-chairman, Francis Kerr; secretary, Wm. N. Gittings; treasurer, W. J. Aulsebrook. Attendance 17.

University of Idaho.—May 23, 1917, Physics Lecture Room. Illustrated lecture on "The Lake Spaulding Development of the Pacific Gas and Electric Company". Attendance 38.

Kansas State Agricultural College.—June 7, 1917, Anderson Hall. Election of officers as follows—president, L. N. Miller; vice-president, Homer Cross; secretary, M. H. Russell; treasurer, R. A. Van Trine; marshal, O. A. Hindman; asst. marshal, R. A. Graves. Attendance 53.

Lafayette College.—May 21, 1917. Papers: (1) "The Electrical Precipitation of Smoke and Suspended Matter" by Allen S. Turner; (2) "Street Lighting" by Stewart M. Wikel. The following officers were elected for the coming year—president, Harry C. Hartung; vice-president, Jacob H. Ritter;

Digitized by Google

secretary, William Lash Lipps; treasurer, William S. Williams. Attendance 16.

Lehigh University.—May 24, 1917, Physical Laboratory. Paper: "Telephone Engineering" by J. L. Montgomery. Motion pictures "Speeding the Spoken Word". Election of officers as follows—president, R. H. Lindsay; vice-president, G. R. Lawall; secretary, R. D. Bean; treasurer, D. C. McGalliard. Attendance 39.

University of Michigan.—May 31, 1917, New Engineering Building. Address by Prof. H. H. Higbie on "Illumination Used in Warfare". Election of officers as follows—chairman, W. R. Harvey; vice-chairman, L. R. Newbold; secretary, T. W. Conant; treasurer, G. S. Heath. Attendance 64.

University of Minnesota.—May 25, 1917. Addresses by Professors Shepardson, Springer and Ryan. Election of officers as follows—chairman, George W. Miller; secretary-treasurer, Ray McKibben; executive committee, Russell H. Ross and Prof. W. T. Ryan. Attendance 23.

University of Missouri.—May 21, 1917, Engineering Building. Election of officers as follows—chairman, A. C. Lanier; vice-chairman, G. C. Black; secretary, D. P. Savant; corresponding secretary, D. I. Cole; assistant secretary, G. A. Irion; treasurer, F. H. Shelton.

Montana State College.—May 18, 1917, Electrical Building. Election of officers as follows—chairman, Roy C. Hagen; secretary, J. A. Thaler; Attendance 18.

North Carolina College of Agriculture and Mechanical Arts.—Election of officers for the coming year as follows—chairman, John R. Hauser; vice-chairman, Frank H. Pritchard; secretary-treasurer, L. C. Flournoy. Attendance 19.

University of North Dakota.—June 4, 1917. Subject: Railway Electrification. Speakers: Roy A. Wehe and Steen Strand. Attendance 10.

Ohio State University.—May 18, 1917, Ohio Union. Spring Banquet. Election of officers as follows—chairman, E. S. Gunn; vice-chairman, H. M. Haase; secretary-treasurer, T. D. Robb. Attendance 40.

Washington State College.—May 25, 1917. Address by Prof. G. C. Warfel on "Application of Electricity to Mining and Metallurgy." Election of officers as follows—president, S. Stites; vice-president, A. E. Smith; secretary, E. Tollefson; treasurer, Jos. Williams; reporter, C. Reis. Attendance 16.

University of Washington.—May 22, 1917, Forestry Hall. Paper: "The Status of the Student Engineer at the Westinghouse Works" by W. Earl Shanley. Attendance 11. Election of officers as follows—chairman, L. P. Kongsted; secretary, C. M. Lubcke. Attendance 11.

Worcester Polytechnic Institute.—May 18, 1917, Electrical Engineering Building. Address by Dr. P. G. Nutting on "Research as a Profession". Election of officers as follows—president, B. Luther; vice-president, A. G. Carlson; secretary-treasurer, N. L. Towle. Joint meeting with local Civil Engineering Society, and local branch of A. S. M. E. Attendance 45.

ASSOCIATES ELECTED JUNE 28, 1917

ABBOTT, WILLIAM RUFUS, General Manager, Chicago Telephone Co., 212 W. Washington St.; res., 5741. Kenmore St., Chicago, Ill.

BENTON, CARL H., Electrical Superintendent, E. I. du Pont de Nemours & Co., Haskell, N. J.

*BERKLEY, H. WALTER, Rate Setter, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 1312 Wood St., Wilkinsburg, Pa.

BERRY, CARL M., Electrical Engineer, Appalachian Power Co., Bluefield, W. Va.; res., 7 Norris St., Cambridge, Mass.

BIGGS, JOSEPH EDGAR, District Sales Manager, Electric Products Co., 122 S. Michigan Ave.; res., 6732 Cornell Ave., Chicago, Ill.

Digitized by Google

BOLLE, HERMAN ALEXANDER, Assistant Engineer, Interborough Rapid Transit Co.; res., 162 W. 84th St., New York, N. Y.

BREITINGER, CHARLES MACCAUGHN, Cost Engineer, Philadelphia Electric Co., 1000 Chestnut St., Philadelphia, Pa.

BUSSELLE, ELMER TOWSHEY, Engineer, Dept. of Utilities, Public Service Commission of Oregon, Salem, Ore.

CALLAHAN, EMMETT, JR., Boardman, Ore.

CARDOZA, WILLIAM H., Chief Electrician, Ermita Sugar Corp., Ermita-Oriente, Cuba.

CHAFFE, J. B., JR., Engineer, Alabama Power Co., 120 Broadway; res., Holland House, New York, N. Y.

CONDON, EDWARD J., JR., Construction Superintendent, Indiana Utilities Co., Angola, Ind.

*COOPER, STUART M., Statistician and Distribution Engineer, New York & Queens Electric Light & Power Co., 444 Jackson Ave., Long Island City, N. Y.

*COULTER, R. S., Commercial Engineer, General Electric Co.; res., 1250 Rosedale Ave., Chicago, Ill.

CRONHEIM, D. H., Assistant Sales Manager, Alabama Power Co.; res., 526 N. 20th St., Birmingham, Ala.

CRUZAT, MANUEL A., Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 618 Kelly Ave., Wilkinsburg, Pa.

CUFF, GEORGE CECIL, Engineer, Toronto Hydroelectric System, 215 Mavety St.; res., 836 Keele St. W., Toronto, Ont.

CUSTER, WILLIAM OSCAR, Power Engineer, with the Subsidaries of Henry L. Doherty & Co., 10 Park Ave., Mansfield, O.

DANN, NORMAN LESLIE, Cable Engineer, Northern Electric Co. Ltd., Shearer St., Montreal, Que.

DANSER, HAROLD W., Industrial Engineer, Supt., Red Bank Dist., Consolidated Gas Co. of N. J.; res., 296 Slocum Pl., Long Branch, N. J.

DAVIS, ARCHIBALD H., JR., Designing Engineer, Consulting Engineering Laboratory, General Electric Co., Schenectady, N. Y.

DAVIS, ARTHUR LINWOOD, Assistant to Engineer, Bangor Railway & Electric Co.; res., 391 Union St., Bangor, Me.

*DAVIS, HENRY EMERSON, Acting Electrical Engineer, New York State Railways, Utica-Syracuse Lines, Gridley Bldg., Syracuse, N. Y.

*DESBECKER, JOHN W., In charge of advertising copy and plans, Redfield Advertising Agency, Inc.; res., 302 W. 22nd St., New York, N. Y.

*DONAHOE, JOHN THOMAS, Electrolysis Investigator, City of Chicago, 614 City Hall; res., 3416 Jackson Blvd., Chicago, Ill.

DONKIN, JONATHAN, JR., Substation Dept., Commonwealth Edison Co.; res., 159 Locust St., Chicago, Ill.

DOUGLAS, DUNCAN CURRIE, Chief District Electrician, Public Service Electric Co. of New Jersey, 15th & Mickle St.; res., 752 Wright Ave., Camden, N. J.

DRUMMOND, WILBUR DON, Assistant Electrical Engineer, R. Thomas & Sons Co.; res., 142 W. 6th St., East Liverpool, O.

DUNLAP, CARL H., Electrical Testing Engineer, Commonwealth Edison Co.; res., 18 W. Chestnut St., Chicago, Ill.

ELLIS JOSEPH, Substation Supervisor, Philadelphia Rapid Transit Co.; res., 5637 Wyalusing Ave., Philadelphia, Pa.

FITZGERALD, GEORGE G., Engineer, Ventura County Power Co., Oxnard; res., Ventura, Cal.

FREEMAN, ROGER MORSE, Construction Engineer, Chase Metal Works, Waterbury, Conn.; res., 235 Arlington Ave., Providence, R. I.

FRIDAY, ELLSWORTH C., Electrical Engineer, General Electric Co.; res., 15 Copley Terrace, Pittsfield, Mass.

FROEBEL, GUENTHER H., Manager, Industrial Div., Westinghouse Electric & Mfg. Co.; res., Fox Apts., Houston, Tex.

Digitized by Google

FRYE, JASON LARKIN, Electrical Engineer, Bisbee, Ariz.; res., Alleghany, Cal.

GARLINGTON, A. C., Supervisor, Electric Div., Panama Canal, Balboa, Canal Zone.

*GAUTHIER, WILLIAM BULL JORDAN, Salesman, Westinghouse Electric & Mfg. Co.; res., 1124 W. Lehigh Ave., Philadelphia, Pa.

GIBBS, ARTHUR A., Electrical Engineer, Dodge Brothers; res., 849 Third Ave., Detroit, Mich.

GOOGINS, WILLIAM, Assistant to Superintendent of Lines, Lehigh Valley Transit Co.; res., 231 N. 15th St., Allentown, Pa.

GREEN, ADONIRAM JUDSON, Student, Cooper Union, New York, N. Y.; res., 73 Paterson St., Paterson, N. J.

GREENE, JOHN F., Electrical Engineer, Continental Motors Corp.; res., 451 Drexel Ave., Detroit, Mich.

GREENWOOD, LEON HENRY, American Telephone & Telegraph Co.; res., 794 4th Ave., North Troy, N. Y.

*HADLEY, J. LEE, Electrical Engineer, Peerless Electric Co.; res., 126 Harmon St., Warren, O.

HANOVER, JOHN WILLIS, Chief Electrician, Collins Co.; res., Thayer Ave., Collinsville, Conn.

HAUCK, ERNEST, Chief Engineer of Power House, Westinghouse Electric & Mfg. Co.; res., 259 High St., Newark, N. J.

HEALEY, FRANCIS ROBERT, Superintendent of Electrical Distribution, Union Gas & Electric Co.; res., 2918 Woodburn Ave., Cincinnati, O.

HEATH, HUBER GALE, Transformer Design, Pittsburgh Transformer Co.; res., 1619 Brighton Rd., Pittsburgh, Pa.

HOBART, CHARLES MONTGOMERY, Salesman, Westinghouse Electric & Mfg. Co.; res., Fox Apartment, Houston, Tex.

HOFFMAN, RAY THOMPSON, Designing Draftsman, Arkansas Valley Railway, Light & Power Co.; res., Maine Hotel, Pueblo, Colo.

HORELICK, SAMUEL, Chief Engineer, Pittsburgh Transformer Co.; res., 1705 Termon Ave., N. S., Pittsburgh, Pa.

HOUSE, BRYAN E., Draftsman, Remy Electric Co.; res., 1224 Iroquois Ave., Detroit, Mich.

HUGHES, GEORGE A., President, Hughes Electric Heating Co., 5660 Waller Ave.; res., 911 Eastwood Ave., Chicago, Ill.

JENKS, JOHN S., Manager, Light & Power Dept., West Penn Power Co., Benedum Trees Bldg.; res., 466 Rebecca St., Pittsburgh, Pa.

JONES, PHILIP CHAPIN, Electrical Engineering Dept., Goodyear Tire and Rubber Co., Akron; res., Wintergreen Ledges, Barberton, O.

KARN, HERBERT CHRISTOPHER, Employment Agent, Northern Electric Co. Ltd., 121 Shearer St., Montreal, Que.

KELLY, DAVID HENRY, Salesman, Allis-Chalmers Mfg. Co.; res., 230 W. 107th St., New York, N. Y.

KNIGHT, E. W., Representative, Westinghouse Electric & Mfg. Co., Interurban Bldg., Columbus, O.

LEMP, HARRY JULIUS, Foreman, Mining Locomotive Assembly, General Electric Co.; res., 1258 E. 20th St., Erie, Pa.

*LESSEY, SAMUEL KENRIC, Assistant to Construction Engineer, Philadelphia Electric Co.; res., 4907 Walnut St., Philadelphia, Pa.

LEWIS, DONALD MCNAUGHTON, Treasurer and General Manager, Livingston-Niagara Power Co.; res., 22 E. Main St., Avon, N. Y.

*LOVELL, WILLIAM VAIL, Testing Dept., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 729 Rebecca Ave., Wilkinsburg, Pa.

MASHBURN, WILLIAM EDWARD, Superintendent of Machinery, Moctezuma Copper Co., Nacozari, Sonora, Mexico.

MATTHEWS, HOWARD DAVID, Electrical Engineer, Designing of Switchboard Apparatus, General Electric Co.; res., 27 Snowden Ave., Schenectady, N. Y.

Digitized by Google

McCLEERY, DONALD WILLIAM, Local Manager, NePage, McKenny Co.,537 Ford Bldg; res., 421 5th Ave. N. Great Falls, Mont.

McLAGAN, ERNEST GEORGE, Assistant Manager Apparatus, Commercial Electrical Supply Co., 1429 Pine St., St. Louis, Mo.

METZENHEIM, HENRY HERMAN, Engineering Dept., Crocker-Wheeler Co., Ampere; res., 169 N. 15th St., East Orange, N. J.

MONAHAN, HARRY WILLIAM, 12 Leighton Road, Waterville, Maine.

PETROWSKY, JOHN FRED, Electrical Tester, In charge of Alternating Current Testing Dept., Crocker-Wheeler Co., Ampere; res., 486 N. 6th St., Newark, N. J.

POESL, CHRISTIAN N., Engineering Draftsman, McCarthy Bros. & Ford, 41 E. Eagle St.; res., 595 Fargo Ave., Buffalo, N. Y.

RALSTON, STUART ALBERT, Assistant Electrical Engineer, Rockford & Interurban Ry. Co.; res., 525 N. Court St., Rockford, Ill.

*RANDALL, HENRY EDWARD, JR., Electrical Engineer, Shawinigan Water & Power Co., 604 Power Bldg.; res., 199 Milton St., Montreal, Que.

REDING, JACOB J., Electrician, Iowa Railway & Light Co.; res., Allison Hotel, Cedar Rapids, Ia.

REDMUND, FRANK, General Plant Superintendent, Chicago Telephone Co., 212 W. Washington St., Chicago, Ill.

ROSS, EDWARD EARL, Service Engineer, Westinghouse Electric & Mfg. Co., Shadyside Works, Pittsburgh; res., 407 Todd St., Wilkinsburg, Pa.

RUGG, HAROLD H., Load Dispatcher, Homestake Mining Co.; res., 709 Main St., Lead, S. D.

RYAN, JOHN ALPHONSUS, Assistant Engineer, H. Boker & Co. Inc., 101 Duane St.; res., 544 W. 156th St., New York, N. Y.

SABANIEFF, ARKADY A., Electrical Engineer, Representative of the Russian Government, American Powder Mills, Maynard; res., 92 Main St., Concord, Mass.

SANFORD, GEORGE BROWNELL, District Manager, Great Western Power Co., Rio Vista, Cal.

SIEGFRIED, JAMES FREDERICK, Chief Electrical Engineer, Alpha Portland Cement Co., Easton, Pa.

SMITH, ALBERT HUGH, Vice-President, Manufacturers' & Inventors' Electric Co., 29-31 Gold St., New York, N. Y.

SNOW, CLARENCE JULIAN, Shop Superintendent, Northwestern Electric Equipment Co., 174 E. 6th St., St. Paul, Minn.

SNYDER, CLAYTON EDWARD, Transformer Design, Pittsburgh Transformer Co.; res., 716 S. Linden Ave., Pittsburgh, Pa.

*STAEHLE, PAUL MAX, Transformer Engineer, General Electric Co.; res., 201 W. Creighton Ave., Fort Wayne, Ind.

STREUBER, RUDOLF GEORGE, Instructor Applied Electricity, New York Electrical School, 38 W. 17th St.; res., 47 W. 93rd St., New York, N. Y.

STRIEBY, WILFRED JAY, Assistant to Engineer, Day & Zimmermann, 611 Chestnut St., Philadelphia; res., 34 Simpson Rd., Ardmore, Pa.

SYDOW, WILLIAM, Electrical Contractor, 1455 Gaylord St.; res., 1069 S. Penn. St., Denver, Colo.

TAYLOR, WILLIAM EDWARD, Engineer, British Westinghouse Electric & Mfg. Co., Trafford Park, Manchester, England.

*TOLHURST, WILLIAM H., Chief Engineer, Casper Refinery, Standard Oil Co.; res., 448 S. Park St., Casper, Wyo.

TREAT, ROBERT, Power and Mining Engineering Dept., General Electric Co., Schenectady, N. Y.

ULRICH, ARTHUR EDWIN, Electrical Engineer, Automatic Electric Co.; res., 4229 Calumet Ave., Chicago, Ill.

VAN ALST, JOHN WILLIAM, JR., Specification Writer, Bell Telephone Co. of Pennsylvania; res., 3332 Smedley St., Philadelphia, Pa.

Digitized by Google

VAN DE WATER, LIVINGSTON, A. C. Motor Engineering, General Electric Co.; res., 40 Bartlett Ave., Pittsfield, Mass.

VICKERY, WALTER OWEN, Superintendent, Federal Light & Traction Co., Trinidad, Colo.

WALLACE, J. KING, District Sales Dept., Continental Fibre Co., 2048 E. 90th St., Cleveland, O.

*WILSON, GEORGE FREDERICK, Substation Operator, Los Angeles Ry. Corp.; res., 1033 S. Burlington Ave., Los Angeles, Cal.

WINKLEY, SAMUEL FREDERICK, Electrical Engineer, Callender's Cable Co., Hamilton House, Victoria Embankment, London, E. C., England.

WOOD, HARRY GARDNER, Switchboard Engineer, Westinghouse Electric & Mfg. Co., 165 Broadway; res., 70 Riverside Drive, New York, N. Y.

*WRIGHT, BURDETTE SHIELDS, Assistant Electrical Engineer, Iowa Railway and Light Co.; res., 1535 Bever Ave., Cedar Rapids, Ia.

Total 98.

*Former enrolled Students.

ASSOCIATES RE-ELECTED JUNE 28, 1917

GENT, E. W., Sales, Esterline Co., Indianapolis, Ind.

RAMSAY, JOSEPH W., Instructor in Electrical Engineering, University of Texas; res., 2406 Wichita St., Austin, Tex.

YOUNG, WILLIAM ALEXANDER, Engineer in charge of Duct and Cable Restoration, U. S. Realty & Improvement Co., 211 Flatiron Bldg., New York, N. Y.

MEMBERS ELECTED JUNE 28, 1917

ARNETT, WILLIAM WOODWARD, JR., Assistant Electrical Engineer, Baldwin Locomotive Works; res., 2116 Pine St., Philadelphia, Pa.

BARTLETT, PERCY HERBERT, Engineer, Meter & Installation Depts., Philadelphia Electric Co., 1000 Chestnut Sts., Philadelphia, Pa.

BRADISH, CHARLES BRESEE, Electrical Engineer, Industrial Control Dept., General Electric Co.; res., 548 Rugby Rd., Schenectady, N. Y.

CALDWELL, BRICE JOHN, Assistant General Manager, Caldwell Electric Corp.; res., 706 W. Hill St., Champaign, Ill.

DEMPSTER, JAMES B., Chief of Electrical Department, City of Des Moines; res., 1421 E. 12th St., Des Moines, Ia.

FREEMAN, HERBERT AUGUSTINE, Chief Draughtsman, Crocker-Wheeler Co., Ampere; res., 128 S. 7th St., Newark, N. J.

GLAUBITZ, HUGH J., Vice-President, Sothman Corporation, 40 Exchange Place, New York; res., 41 Caryl Ave., Yonkers, N. Y.

HOWARD, BASIL FENWICK, Electrical Engineer, Mountain States Telephone & Telegraph Co., 1421 Champa St., Denver, Colo.

HUNTER RICHARD B., Designing Engineer, Cutler-Hammer Mfg. Co.; res., 1625 Grand Ave., Milwaukee, Wis.

JONES, ALFRED HOWARD, General Manager, McComb & Magnolia Light & Railway Co., McComb, Miss.

KUYLENSTJERNA, ADOLF, Mechanical and Electrical Engineer, American Railway Co., 917 Witherspoon Bldg., Philadelphia, Pa.

FELLOW ELECTED JUNE 28, 1917

JACOBS, ERNEST H., Chief Engineer and Assistant General Manager, Electrical Engineers Equipment Co., 711 Meridian St., Chicago, Ill.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meetings mentioned below, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection

Digitized by Google

to these transfers should be filed at once with the Secretary.

Recommended for Transfer June 15, 1917.

To the Grade of Member

BAUGHAN, ALEX. E., Station Superintendent, Pennsylvania Water & Power Co., Holtwood, Pa.

EALES, HERBERT W., Chief Electrical Engineer, Union Electric Light & Power Co., St. Louis, Mo.

JACKSON, NEWTON, Assistant to Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

REYNEAU, P. O., Distribution Engineer, Detroit Edison Co., Detroit, Mich.

ROBERTS, T. C., Chief Engineer, United Verde Copper Co., United Verde & Pacific Railway Co., Clarkdale, Ariz.

Recommended for Transfer June 21, 1917.

To the Grade of Member

PETTY, DAVID M., Superintendent, Electrical Dept., Bethlehem Steel Co., Bethlehem, Pa.

TRANSFERRED TO THE GRADE OF MEMBER JUNE 28, 1917

GROVE, WILLIAM H., Inspector for Electrical Engineer, Edison Electric Illuminating Co. of Brooklyn, Brooklyn, N. Y.

JEFFERSON, W. H., Electrical Engineer, Cutler-Hammer Mfg. Co., Milwaukee, Wis.

PANNELL, ERNEST V., Engineer, British Aluminum Co. Ltd., Toronto, Ont.

SMITH, IRVING B., Head of Research Dept., Leeds & Northrup Co., Ambler, Pa.

SUTTON, H. CRAIG, Assistant to Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

TOMPKINS, H. K. V., Chief Engineer, Texas Gas & Electric Co., Houston, Tex.

TRANSFERRED TO THE GRADE OF FELLOW JUNE 28, 1917

SOTHMAN, P. W., Consulting Engineer, New York, N. Y.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before July 31, 1917.

Anderson, R. S. (Member), New York, N. Y.
Bailey, H. H. (Member), Columbus, O.
Blanchard, T. S., Wilmington, Del.
Broder, G. A., Cleveland, O.
Bush, G. P., Chicago, Ill.
Clothier, H. W., Hebburn-on-Tyne, England.
Cushing, R. W., Washington Barracks, D. C.
Delcott, H., Melbourne, Australia.
DeWitt, H., Detroit, Mich.
Eitzen, L. C., New York, N. Y.
Erickson, C. J., Los Angeles, Cal.
Folds, G. R. (Member), Chicago, Ill.
Freeman, F. C. (Member), Philadelphia, Pa.
Hess, V. E., Topeka, Kans.
King, A. B., Minneapolis, Minn.
Kirkman, B., New York, N. Y.
Litzebauer, F. A., Newark, N. J.
McGregor, A. J., New York, N. Y.
McKenzie, W. L., Lethbridge, Alta.
Moore, R. W. E. (Member), East Pittsburgh, Pa.
Morris, F. W. (Member), Brooklyn, N. Y.
Nash, E. J., Butte, Mont.
Nukiyama, H., Sendai, Japan.
Palmer, J. B., Stratford, England.
Peck, H. C., Coatesville, Pa.
Putnam, R. G., E. Pittsburgh, Pa.
Reid, R., San Francisco, Cal.
Ryan, P. D., Washington, D. C.
Salicis, G. A., Grand Mere, Quebec

Digitized by Google

Schultz, H. W., Beloit, Wis.
Smilari, M. A., Pittsfield, Mass.
Suen, S. T., Amoy, China.
Walker, W. J. (Member), Schenectady, N. Y.
Wallace, W. S., Pittsburgh, Pa.
Ward, B. E., Washington, D. C.
Wise, L. D., Fort Mills, P. I.
Total 36.

STUDENTS ENROLLED JUNE 28, 1917

9058 Hartwig, A. E., Wentworth Inst.
9059 Rupp, W., Univ., of Wash.
9060 Benjamin, M. S., Yale Univ.
9061 Long, M. B., Univ. of Neb.
9062 Rouse, C. H., Mich. Agri. Coll.
9063 Reyes, H. B., Cornell Univ.
9064 Bussey, R. E., Cornell Univ.
9065 Greene, L. W., Wentworth Inst.
9066 Sammis, W. H., Columbia Univ.
9067 Gilchrist, F. W., Ohio State Univ.
9068 Meyer, C. C., Univ. of Penna.
9069 Pack, E. P., Wentworth Inst.
9070 Duren, G. M., Univ. of Mo.
9071 Wurtenburg, W. G., Wentworth Inst.
9072 Austermiller, E., Rose Poly. Inst.
9073 Burger, E. J., N. Y. Elec. Sch.
9074 Cowan, L. A., Jr., Rensselaer Poly. Inst.
9075 Towle, N. L., Worcester Poly. Inst.
9076 Sporn, P., Columbia Univ.
9077 Underwood, F. J., Rice Inst.
9078 Underwood, P. H., Rice Inst.
9079 Sporn, M. E., Poly. Inst. of Bklyn.
9080 Glidden, G. M., Mich. Agri. Coll.
9081 Stallings, W. A., Colo. Agri. Coll.
9082 Hodgdon, R. E., N. H. College.
9083 Dudley, W. A., N. H. College.
9084 Beers, H. A., Bucknell Univ.
9085 Hickling, W. G., Yale Univ.
9086 Lowry, R. S., Ohio State Univ.
9087 Taylor, W. D., Bliss Elec. Sch.
9088 Higgins, D. F., Worcester Poly. Inst.
9089 Knapp, P. R., Worcester Poly. Inst.
9090 Schoch, A. J., Univ. of Illinois.
9091 Ketch, J. M., Univ. of Illinois.
9092 Hammond, F. M., Cornell Univ.
9093 Murata, M., Univ. of Illinois.
9094 Pendarvis, H. R., Univ. of Ill.
9095 Wu, W. Y., Univ. of Illinois.
9096 Starr, I. B., Univ. of Neb.
9097 Miller, H. W., Carnegie Inst. of Tech.
9098 Akenhead, J. E., Univ. of Wis.
9099 Grimm, J. E., Jr., Univ. of Wis.
9100 Ginns, D., Univ. of Penna.
9101 Swanson, G. W., Pratt Inst.
9102 Potter, G. E., Univ. of Ill.
9103 Crossley, A., Univ. of N. D.
9104 Toppel, J. S., Armour Inst. of Tech.
9105 Lawson, F. I., Carnegie Inst. of Tech.
9106 Lehmann, F. A., Lafayette Coll.
9107 Bersie, H. G., Northwestern Univ.
9108 Novak, F. L., Pratt Institute.
9109 Rau, E. S., Lehigh University.
9110 Carter, R. E., Univ. of Mo.
9111 Addy, J. G., Jr., Pratt Inst.
9112 Woodward, A. A., Pratt Inst.
9113 Holly, W. B., Pratt Inst.
9114 Wood, H. B., Univ. of Neb.
9115 Ostergren, C., Yale Univ.
9116 Humphrey, H. C., Worcester Poly. Inst.
9117 Webber, T. T., Pratt Institute.
9118 Teschner, A., Pratt Institute.
Total 61.

OBITUARY

MR. WILLIAM SMITH HORRY, electrical engineer with the Union Carbide Company, died at Atlantic City on April 14, 1917. Mr. Horry was an Associate in the Institute. He had done a great deal of research work and made many inventions along electrical lines.

MR. LEWIS R. POMEROY, consulting engineer, died suddenly on May 7, 1917. Mr. Pomeroy was an authority on railroad shop layouts and equipment and had made valuable studies in the matter of electrification of steam roads. He had been connected with the Carnegie Steel Company, American Locomotive Company and the General Electric Company.

PERSONAL

MR. H. E. J. GLIENKE has formed a partnership with Mr. W. H. Carlsen under the name of the "Wm. H. Carlsen Company," electrical contractors, 4920 Cortez St., Chicago, Ill.

Digitized by Google

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From April 3d, to June 1, 1917)

Unless otherwise specified, books in this list have been donated by the publishers. The Society does not assume responsibility for any statements made. They are taken either from the preface or the text of the book.

GENERAL INSTRUCTIONS AND METHODS OF ANALYSIS AND CHEMICAL CONTROL FOR USE IN THE FACTORIES OF THE CUBAN-AMERICAN SUGAR COMPANY.

By Guilford L. Spencer, N. Y., The Cuban American Sugar Company, 1916. 39 pp., 8½x6 in., paper, $1.

The purpose of this book is to supply methods that are applicable in all the company's factories, in obtaining the data required for report sheets and permanent records. Definitions of terms used by the company are included.

GAS CHEMISTS' HANDBOOK.

Compiled by Technical Committee, Sub-Committee on Chemical Tests, 1916, of the American Gas Institute. C. C. Tutweiler, Chairman, A. F. Kunberger, Editor, N. Y., American Gas Institute. 354 pp., 9x6 in., 70 illus., cloth, $3.50.

The present handbook, a revision of the one compiled in 1914, presents methods for sampling and testing the materials used in gas manufacture. Contents: Raw Materials; Products of Gas Manufacture; Impurities in Gas; Tar Products; Miscellaneous and Tables.

STRESSES IN WIRE-WRAPPED GUNS AND IN GUN CARRIAGES.

By Lieut. Col. Colden L'H. Ruggles, N. Y., John Wiley & Sons, Inc., Lond., Chapman & Hall, Ltd., 1916. 11 + 259 pp., 9x6 in., cloth, $3.

Explains a number of the important engineering principles underlying the design of wire-wrapped guns and of gun carriages. Originally prepared for the use of the cadets of the U. S. Military Academy. Contents: Elastic Strength of Wire-Wrapped Guns; Determination of the Forces Brought upon the Principal Parts of the 3-inch Field Carriage and a Disappearing Gun Carriage by the Discharge of the Gun; Stresses in Parts of Gun Carriages; Toothed Gearing; Counter Recoil Springs.

TELEGRAPHY.

A detailed Exposition of the Telegraph System of the British Post Office. 3d ed. rev. and enl. N. Y., The Macmillan Co.; Lond., Whittaker & Co., 1916. 20+985 pp., 7½x5 in., 630 illus., cloth, $3.50.

Intended as a detailed exposition of the telegraph practice of the British Post Office and for students. Mathematics is avoided. This edition has been revised to include the latest practice and to correct errors.

THE STORY OF BETHLEHEM STEEL.

By Arundel Cotter, N. Y., the Moody Magazine and Book Co., 1916. 65 pp., 7½x5 in., 8 pl., cloth, 75 cts.

Contents: Town Founded by Moravian Colonists; When Schwab Went Down to Bethlehem; Bethlehem and the War Stock Boom; Schwab's Theories.

GASOLINE AND HOW TO USE IT.

By G. A. Burrell, Bost., Oil Statistical Society, Inc., 1916. 281 pp., 6x4½ in., illus., cloth, $1.50.

The preface states that the aim of this book is to provide an intelligent understanding of the use of gasoline, to assist the motorist and the farmer, and to give the history of gasoline and petroleum.

MICROSCOPIC EXAMINATION OF STEEL.

By Henry Fay. Wiley Engineering Series No. 3. N. Y., John Wiley & Sons; Lond., Chapman & Hall, Ltd., 1917. 18 pp., 9x6 in., 32 pl., cloth, $1.25.

The material contained in this volume was originally issued by the Ordnance Department U. S. A. and was intended for the exclusive use of inspectors of ordnance material, but is now published for the use of others interested in the inspection of steel. It is meant only to present a mere outline of metallographic methods illustrating typical examples, but is not for use as a text-book. It is intended particularly for those who are in need of help in the interpretation of results. Over two thirds of the volume consists of full page plates.

STEAM TURBINES.

A Treatise Covering U. S. Naval Practice. By G. J. Myers. Annapolis, The U.S. Naval Institute, 1917. 7+246 pp., 12x8 in., 179 illus., 23 diagrams, 9 pl., cloth, $4.50

This book has been prepared to meet the needs of an elementary treatise on steam turbines for the use of midshipmen at the U. S. Naval Acad-

Digitized by Google

emy, and deals mainly with types found in the U. S. Naval Service.

LABORATORY MANUAL OF BITUMINOUS MATERIALS.

For the Use of Students in Highway Engineering. By Prevost Hubbard. N. Y., John Wiley & Sons; Lond., Chapman & Hall, Ltd., 1916. 11+153 pp., 9x6 in., 38 illus., cloth, $1.50.

Certain fundamentals not strictly a part of laboratory work have been included as a guide to students not well versed in the nomenclature, classification, and uses of bituminous materials.

MODERN UNDERPINNING.

Development, Methods and Typical Examples. By Lazarus White and Edmund Astley Prentis, Jr. (Wiley Engineering Series No. 2) N. Y., John Wiley & Sons, Inc; Lond., Chapman & Hall, Ltd. 1917. 12+94 pp., 9x6 in., 48 illus. 1 pl., cloth, $1.50.

Intended to exhibit, by means of photographs and drawings, the essential steps in underpinning as illustrated by the methods used in subway construction in New York City. Only enough text to supplement the illustrations included. Contents; General Aspects; Development of Underpinning and Methods; Shores, Needles, and Foundation Reinforcements; Specific Examples of Underpinning; Appendix.

INSTRUCTIONS TO LOCATING ENGINEERS AND FIELD PARTIES.

By F. Lavis. N. Y., McGraw-Hill Book Co., Inc. (c. 1916) 44 pp., 9x6 in., 9 diagrams, cloth, $1. (gift of the author.)

Reproduced in abridged form from "Railroad Location Surveys and Estimates". Originally prepared for the use of field parties working under his direction in the United States, afterwards modified for use in South America and finally prepared in the present form for use in China. They are intended to secure uniform practice in making surveys and in the compilation of the results in the form of maps, estimates, etc.

FRENCH MEASURE AND ENGLISH EQUIVALENTS.

By John Brook, N. Y., Spon & Chamberlain; Lond., E. & F. N. Spon, 1917. 7+80 pp., 4x3, 40 cts.

Vest-pocket size. Gives the English equivalents of the metric measures of length and weight and of the old French, Prussian, Austrian and Russian measures of length. A table for reducing the usual vulgar fractions of the inch to decimals is also given. The English equivalents are given in decimal fractions, correct to six places, and approximately in vulgar fractions as well. Intended for engineers, manufacturers and workmen.

STEAM PIPING.

Its Economical Design and Correct Layout. By A. Langstaff Johnson, Jr., N. Y., The Engineering Magazine Co., 1916. 6+62 pp., 5x8, 3 illus., 4 diagrams, cloth, $2.

Consolidated and revised from a series of articles published in the *Engineering Magazine* in 1915. Analyzes the factors governing the flow of steam in pipes, and presents a group of curves for use in solving the problems of practical installation and determining the most economical size of pipe to select for any given conditions. Contents: How to Find the Right Pipe Sizes; Special Conditions Affecting Low-Pressure Systems; and Savings Obtainable from Exhaust Steam.

HENDRICKS' COMMERCIAL REGISTER OF THE UNITED STATES.

For Buyers and Sellers. Twenty-fifth Annual Edition, N. Y., S. E. Hendricks Co., Inc., 1916. 1738 pp., 8x10 in., illus., cloth, $10.

A directory of producers, manufacturers, dealers and consumers connected with the architectural, contracting, electrical, engineering, hardware, iron, mechanical, mill, mining, quarrying, railroad, steel and kindred industries.

RIVER DISCHARGE.

By John Clayton Hoyt and Nathan Clifford Grover. 4th ed. rev. and enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 12 + 210 pp., 16x9 in., 23 illus., 7 pl., 2 maps, 1 diagram, tab., cloth, $2.

This edition has been revised and brought up to date. Chapter V, "Discussion and Use of Data" has been largely rewritten, and chapter VI has been expanded to cover the field of hydrology. Contents: Introduction: Instruments and Equipment; Structures from which Measurements are Made; Velocity-area-stations; Weir Stations; Discussion and Use of Data; Hydrology as Related to Stream Flow.

SPONS' ELECTRICAL POCKET-BOOK.

A Reference Book of General Electrical Information, Formulas and Tables for Practical Engineers. By Walter H. Molesworth. N. Y., Spon & Chamberlain; Lond., E. & F. N. Spon, Ltd., 1916. 488 pp., 4x7 in., 325 illus., cloth, $2.

This book has been written for practical engineers and it has been the aim to treat all subjects concisely and to avoid intricate mathematics. Full metric conversion tables have been inserted.

Digitized by Google

HOW TO FIND FACTORY COSTS.

By C. Bertrand Thompson. Chic., N. Y., Lond., A. W. Shaw Co., 191 pp., 10x7 in., 51 charts, 1 diagram, 1 tab., cloth, $3.

It is stated that this book is broad enough to apply to all kinds of industries, and is intended to be useful to the accountant as well as the factory head.

THE BAROMETRICAL DETERMINATION OF HEIGHTS.

A Practical Method of Barometrical Levelling and Hypsometry for Surveyors and Mountain Climbers. By F. J. B. Cordeiro. 2 ed. rev. and enl. N. Y., Spon & Chamberlain; Lond., E. & F. N. Spon, Ltd., 1917. 26 pp., 7x4 in., cloth, 50 cts.

This little volume was an essay originally entered in the Hodgkins Prize Competition held under the auspices of the Smithsonian Institution, and was awarded honorable mention.

DOCUMENTS GOVERNING THE CONSTRUCTION OF A BRIDGE.

Including a Reprint of the Specifications, Proposal, Contract and Bond of the Columbia River Interstate Bridge, a Description of the Structure, and a Discussion of the Function of Specifications. By E. E. Howard, N. Y., John Wiley & Sons, Lond.; Chapman & Hall, Ltd., 1916. 113 pp., 8x11 in., 1 pl., paper, $1.

These specifications have been printed in book form with the thought that they may be of value in suggesting satisfactory substance and arrangement for like documents, being the product, the author states, of a variety of experiences, of technical opinions and engineering judgments reached only after years of practice.

QUESTIONS AND ANSWERS RELATING TO MODERN AUTOMOBILE DESIGN, CONSTRUCTION, DRIVING AND REPAIR.

A practical treatise consisting of thirty-nine lessons in the form of questions and answers written with special reference to the requirements of the nontechnical reader desiring easily understood explanatory matter relating to all branches of automobiling. By Victor W. Page, rev. and enl. ed. N. Y., The Norman W. Henley Publishing Co., 1917. 15+701 pp., 5x8 in., 397 illus., 3 pl., cloth, $1.50.

FRYE'S TABLES FOR ASCERTAINING THE VALUE OF GOLD-QUARTZ SPECIMENS.

By Jason S. Frye. Downieville, Cal., Jason S. Frye, (privately printed) 1916. 56 pp., 4x3 in., leather, $1 (gift of the author).

Vest-pocket book of tables for finding the percentage of gold and the value per ounce from the specific gravity of gold-quartz specimens containing different amounts of gold.

MUNICIPAL ENGINEERING PRACTICE.

By A. Prescott Folwell. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 11+422 pp., 9x6 in., 112 illus., 1 pl., cloth, $3.50.

This book has been written to treat at greater length practical information concerning street cleaning, public comfort stations and other subjects not treated in most of the text-books on municipal engineering. Contents: Fundamental Data; The City Plan; Street Surface Details; Bridges and Waterways; City Surveying; Street Lights, Signs and Numbers; Street Cleaning and Sprinkling; Disposing of City Wastes; Markets, Comfort Stations and Baths; Parks, Cemeteries and Shade Trees.

A HANDBOOK FOR CANE-SUGAR MANUFACTURERS AND THEIR CHEMISTS.

By Guilford L. Spencer. 5th ed. enl. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 15+529 pp., 7x4 in., 83 illus., 1 pl., leather, $3.50.

The book is divided into two parts; Manufacture of Cane-Sugar, and Sugar Analysis; a chapter is also included on sugar refining as practised in the United States. The Chemical section of the book has been revised to meet the conditions of the very large factories now in operation.

CENTRAL-STATION ELECTRIC SERVICE.

Its Commercial Development and Economic Significance as Set Forth in the Public Addresses (1897-1914) of Samuel Insull. Edited, with an Introduction by William Eugene Kelly. Chic. Privately printed, 1915. 39+495 pp., 9x6 in., 105 illus., 36 pl., cloth. (gift of the author.)

A collection of forty speeches bearing on central station electric service, delivered by the author between 1897 and 1914. The editor states that these addresses are the work of one who has led the way to new conceptions of the economic functions of central station electric service, and that much information of historical value, some of it never before published, is scattered through the book.

Digitized by Google

THE VENTILATION HAND BOOK.

The Principles and Practice of Ventilation as Applied to Furnace Heating; Ducts, Flues and Dampers for Gravity Heating; Fans and Fan Work for Ventilation and Hot Blast Heating. By Charles L. Hubbard. N. Y., Sheet Metal Publishing Co., 1916. 218 pp., 8x6 in., 137 illus., cloth, $2.

A series of questions, answers and descriptions, with illustrations, arranged from a series of articles prepared for *Sheet Metal*. Care has been taken to keep all descriptions and mathematical work well within the understanding of the student and beginner.

MINE GASES AND VENTILATION.

A Reference Handbook Combining Theory and Practice of Coal Mining: Designed to meet the needs of all students of coal mining including mining engineers, mine superintendents, foremen, firebosses, shotfirers and miners preparing for examination for certificates of competency. By J. T. Beard. N. Y., Hill Publishing Co., 1916. 206 pp., 7x5 in., flexible cloth, $2. (gift of the author.)

Composed of material on the atmosphere, gases and ventilation of mines which has appeared in pocket book form, in the "Study Course in Coal Mining" department of *Coal Age* since March, 1913, and which was prepared in response to requests from coal miners who wished to know the development of formulas, the explanation of principles and the most approved and generally adopted methods. Contents Air; Heat; Mine Gases; Theory of Ventilation; Practical Ventilation, Addenda.

MUNICIPAL ACCOUNTING.

By DeWitt Carl Eggleston. N. Y., The Ronald Press Co., 1914. 22+456 pp., 9x6 in., 113 diagrams, ½ leather, $4.

Intended to furnish practicing accountants, municipal accountants and students with a complete method of municipal accounting, representing the best modern practice. The methods described are intended for the larger cities, but a special chapter on accounting for smaller cities is included. Many of the methods employed in New York are presented.

STEAM POWER.

By C. F. Hirshfeld and T. C. Ulbricht. N.Y., John Wiley & Sons, Inc. Lond., Chapman & Hall, Ltd., 1916. 8+420 pp., 8x5 in., 91 illus., Cloth, $2.

An attempt to collect in a comparatively small book such parts of the field of steam power as should be familiar to engineers whose work does not require that they be conversant with the more complicated thermodynamic principles considered in advanced treatments. Mathematical treatment of the subject has been eliminated to the greatest possible extent. Intended for use as a text-book by students of civil engineering and in teaching power plant operators.

AZIMUTH.

By George L. Hosmer. 2nd ed. rev., N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 5+73 pp., 5x7 in., 6 illus., leather, $1.

This handbook is intended to present in compact form certain approximate methods of determining the true bearing of a line, together with the necessary rules and tables arranged in a simple manner so that they will be useful to the practical surveyor. This edition contains a new method for finding the azimuth by an observation on the pole star at any hour angle when the local time is known. The tables of the sun's declination have been extended to 1919 and new star maps are given.

HAND BOOK OF CASINGHEAD GAS.

By Henry P. Westcott. Erie, Metric Metal Works, 1916. 9+274 pp., 5x8 in., illus., cloth, $2.50.

Method, statistics, etc., intended to supply information on the processes used for extracting gasoline from natural gas. Based on visits to many existing plants and a study of their reports. Contents: General Physical Properties of Casinghead Gas Wells; Construction of Pipe Lines; Measuring Casinghead Gas; Gasoline Plant, Compression Method; Gasoline Plant, Absorption Method; Transportation of Gasoline; Miscellaneous.

A DISCUSSION OF THE PRINCIPLES AND PRACTICE UNDERLYING CHARGES FOR WATER, GAS, ELECTRICITY, COMMUNICATION AND TRANSPORTATION SERVICES.

By Harry Barker. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 14+387 pp., 9x6 in., cloth, $4.

The author's aim has been to present, concisely and impartially, and as far as possible, in non-technical language, the diverse phases of rate making for public utilities, including a comprehensive discussion of (1) such corporation and municipal activities as affect service and rates; (2) the trend of public opinion and Court and commission decisions; and (3) the most important engineering and economic problems involved, with the hope that it will prove of service to lawyers and legislators, to editorial writers of the daily press, to students of municipal affairs, and to the general public. Contents: Development

Digitized by Google

of Utility Regulation, Utility Privileges and Obligations, Rights of the Public; Product and Service Companies, Some Definitions of Rates and Services; Various Bases for Rates; Details of the Cost-of-Service Study of Rates, Test for Fixed and Operating Charges; Fair Value of a Utility Property; Valuation as an Engineering Task, Appraisal of Land and Water Rights; Reasonable Return, Interest, Compensation for Risk and Attention, Extra Profits; Depreciation as it Affects Utility Rates; Miscellaneous Problems Indirectly Related to Rate-Making; Problems of Railway Rates; Problems of Express Transportation Rates; Rate Problems of Street and Interurban Railway Transportation; Problems of Water Rates; Rate Problems of Gas Utilities; Rate Problems of Electricity Supply Works; Problems of Telephone Rate-Making; Appendix A. B. C. D.

TUBE MILLING.

A Treatise on the Practical Application of the Tube Mill to Metallurgical Problems. By Algernon Del Mar. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10+159 pp., 6x9 in., 70 illus., 1 pl., cloth, $2.

Covers the use of the conical and cylindrical tube mills for grinding ores, indicating in detail the best means of obtaining capacity at the least cost, and describing recent installations. It is, the author states, the only book entirely devoted to the subject. Contents: General Description; Amalgamating with the Tube; Grinding Ores with the Tube Mill for Flotation; Crushing Efficiencies; The Use of Wrought Iron and Alloy Steel; Appendix.

THE NAVAL ARCHITECTS' AND SHIPBUILDERS' POCKET-BOOK OF FORMULAS, RULES, AND TABLES.

And Marine Engineers' and Surveyors' Handy Book of Reference. By Clement Mackrow and Lloyd Woodland. 11th ed. thoroughly rev., with a section on aeronautics. N. Y., The Norman W. Henley Publishing Co., 1916. 12+742 pp., 6x4 in., 150 illus., flexible leather, $5.

The continual development of the science of naval architecture and the tendency towards standardization and regulation of parts of the structure and equipment of ships have created a need, the authors state, for a new edition of this work. Their object has been, as in former editions, to condense into a compact form all the data and formulas ordinarily required by the shipbuilder or naval architect. A new section on Speed and Horse-Power has been inserted, together with a brief description of modern methods of powering and determining forms suitable from a propulsive standpoint; the sections on strength of materials, riveted joints and stresses in ships have been considerably extended; information on British standard sections, screws, keys, etc., has been added as well as two new sections on aeronautical matters. The remaining subjects treated, which were also in previous editions, have been brought completely up-to-date.

RAILWAY TRACK ECONOMICS.

A Tabloid Treatise Upon Railroad Problems. By August E. Liebman. rev. ed. Chic., (privately printed) 1916. 66 pp., 6½x5 in., leather, $3. (gift of the author.)

The author states that he presents in tabloid form some criticism and recommendations for solving the problems of maintenance costs.

VALUATION, DEPRECIATION AND THE RATE-BASE.

By Carl Ewald Grunsky and Carl Ewald Grunsky, Jr. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 8+387 pp., 9x6 in., cloth, $4. (gift of the author and publisher.)

The author states that this book is the result of personal contact with the valuation problem. Special consideration has been given to a discussion of the non-agreement of the actual life of articles which have a limited period of usefulness with their probable or normal life. The tables included are not only intended for valuation engineers, but for any one having problems of finance and bonding to solve. Contents: Introduction and General Notes; Definitions; Fundamental Principles; Essentials of Value; Elements Which Reduce Value; The Effect of the Non-Agreement Between Actual and Probable Life Upon the Determination of Depreciation; The Purpose of the Appraisal; The Fixing of Rates; Possible Procedures when the Rates for a Public Service are to be Fixed; Notes on the Determination of the Value of Real Estate in Eminent Domain Proceedings and for Rate Fixing Purposes; The Value of a Water-Right and of Reservoir and Watershed Lands; The Accounting System; The Valuation of Mines and Oil Properties by C. E. Grunsky, Jr., Tables.

THE INDUSTRIAL AND ARTISTIC TECHNOLOGY OF PAINT AND VARNISH.

By Alvah Horton Sabin. 2d ed. rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 10+473 pp., 9x6 in., 10 pl., 10 illus., cloth, $3.50.

Written to give a correct general outline of the subject, with a brief account of the modern use of paints and varnishes, and of the principles involved in their fabrication and application. This edition is nearly one-third larger than the first one and takes cognizance of the changes in the character of the cheaper varnishes due to the use of tung oil.

Digitized by Google

THE WORLD'S MINERALS.

By Leonard J. Spencer, with an appendix by W. D. H. Hamman. N. Y., Frederick A. Stokes Co., 1916. 11+327 pp., 8x6 in., 40 pl., 21 diagrams, cloth, $2.75.

An attempt to present a popular and readable account, in the main confined to the 116 species of the more common simple minerals, which will help the student collector to identify his own specimens. Forty color-plates are included.

INDUSTRIAL PREPAREDNESS.

By C. E. Knoeppel. N. Y., The Engineering Magazine Co., 1916. 6+145 pp., 8x5 in., cloth, $1.

A study of Germany's military and industrial preparedness intended to point the way to national greatness through the right kind of social, industrial and military preparedness.

USE OF WATER IN IRRIGATION.

By Samuel Fortier. 2d ed. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1916. 16+325 pp., 8x6 in., 75 illus., 8 pl., cloth, $2.

The first edition, which appeared in 1914, dealt with the agricultural side of irrigation. In the present edition the article on the measurement of water has been revised and enlarged, and a new one added on sewage irrigation. A new chapter on the "Use of Water in Foreign Countries" is a most important addition to the book. Contents: Introduction; The Irrigated Farm; The Necessary Equipment and Structures; Methods of Preparing Land and Applying Water; Waste Measurement; Delivery and Duty of Water; Irrigation of Staple Crops; Use of Water in Foreign Countries.

ENGINEERING ANALYSIS OF A MINING SHARE.

By J. C. Pickering. N. Y., McGraw-Hill Book Co., Inc; Lond., Hill Publishing Co., Ltd., 1917. 8+95 pp., 9x6 in., cloth, $1.50. (gift of the author.)

An endeavor to set forth the considerations which enter logically into the analysis of a mining venture, approached from an engineering viewpoint. Contents: Classification of Mining Properties; Development Companies; Elements to be Considered in the Analysis of a Mining Report; Operating Profits vs. Dividends; Determination of the Value of a Mine or Mining Share; Valuing Mine Products; World's Gold Production with a Review of the World's Greatest Goldfield; Mining vs. Industrial and other Types of Investments with an Analysis of the Affairs of Typical Mining Companies.

ELECTRIC TRACTION.

A Treatise on the Application of Electric Power to Tramways and Railways. By A. T. Dover. N. Y., and Lond., Whittaker & Co., 1917. 18+667 pp., 9x6 in., 518 illus., 5 pl., cloth.

Intended for engineers and advanced students. Representative examples of modern tramway and railway practice are included, but detailed accounts of electrification have been omitted and generating stations and transmission lines have not been considered. Contains a bibliography on electrification, and a number of worked examples have been included in the text. Contents: Mechanics of Train Movement; Motors; Control; Auxiliary Apparatus; Rolling Stock; Detailed Study of Train Movement; Track and Overhead Construction; Distributing Systems and Substations.

STANDARD METHODS FOR THE EXAMINATION OF WATER AND SEWAGE.

By the American Public Health Association. 3d ed. Bost., American Public Health Association, 1917. 115 pp., 10x7 in., 1 illus., cloth, $1.25.

This volume is the result of the combined labors of three committees namely: the committee of the American Public Health Association; American Chemical Society; and the Association of Official Agricultural Chemists. The 1912 edition has been modified by the addition of methods for the examination of sewage sludge and muds, the analysis of chemicals used in the treatment of water, and the determination of chlorine. Changes also have been made in the technique of existing methods. Bacteriological, chemical and microscopical bibliographies are included.

A HANDBOOK OF BRIQUETTING.

By G. Franke. Translated by Fred C. A. H. Lantsberry vol. 1. The Briquetting of Coals, Brown Coals, and Other Fuels Phila., J. P. Lippincott Co.; Lond., Charles Griffin and Co., Ltd., 1917. 19+631 pp., 9x6 in., 225 illus., 9 pl., cloth, $9.

This book is not only intended as a handbook for those engaged in the industry, but can be used as a text book in schools of mining and metallurgy and technical high schools. The translator adds that the object of the translation is to put in the possession of English industrial leaders, knowledge which other countries have been compelled to acquire.

THE MECHANISM OF THE LINOTYPE.

A Complete and Practical Treatise on the Installation, Operation and Care of the Linotype, for the Novice as well as the Experienced Operator. By John S.

Digitized by Google

Thompson. 6th ed. rev. Chic., The Inland Printer Co., 1916. 10+280 pp., 7x5 in., 77 illus., 1 por., leather, $2.

The present edition of this text-book embodies all the improvements made in the Linotype to the present time. A brief sketch is given of Ottmar Mergenthaler, the inventor of the Linotype.

A MANUAL OF FIRE PREVENTION AND FIRE PROTECTION FOR HOSPITALS.

By Otto R. Eichel. N. Y., John Wiley & Sons; Lond., Chapman & Hall, Ltd., 1916. 5+69 pp., 7½x5 in., cloth, $1.

An outline of the principles of fire prevention and protection, with indications for their application in institutions housing the sick, based on the personal observation and study of the author, who is Director of the Division of Sanitary Supervisors, New York State Department of Health.

PRACTICAL SHEET METAL DUCT CONSTRUCTION.

A Treatise in the Construction and Erection of Heating and Ventilating Ducts. By William Neubecker. N. Y., The Sheet Metal Publishing Co., 1916. 194 pp., 8x6 in., 217 illus., cloth, $2.

The plan of the present work is to take up each operation, and by means of descriptions (usually illustrated) to show all operations incident to the construction and erection of heating and ventilating ducts.

Digitized by Google

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-247. Draftsman (Electrical) experienced on power station and substation layout. Location Brooklyn, N. Y.

V-248. Draftsman and Checker, experienced on power station and substation wiring diagrams. Steady position. Location Brooklyn, N. Y.

V-249. A prominent manufacturer of electrical instruments with old established business; has opening for district sales agent, Chicago territory. This opening can be secured only by high-grade man known to the trade in this territory.

V-250. Opportunity for several young, technically trained men, preferably with some practical experience, with public service commission of New York. Salary about $90 per month to start. Please give particulars as to training, age, and experience.

MEN AVAILABLE

778. Graduate Electrical Engineer, with four years' experience in design, and several years of shop and of general office work, wishes position in engineering or production department of a manufacturing concern. Correspondence invited.

779. Position desired as assistant to electrical engineer, superintendent or consulting engineer, by M. I. T. graduate, (E. E.). Seven years as electrical engineer in charge of construction and sales for Westinghouse Co. Past two years with leading engineering corporation, Boston, designing power and industrial plants. Age 35, married; minimum salary $200 monthly.

780. Electrical Engineer, technical graduate, (1908). Nine years' experience covering inspection, installation and operation of insulated wires and cables, and also public service operation and engineering. Position in New York City or New England states preferred.

781. A Russian Electrical Engineering graduate of an American university, with broad sales, construction and public utility experience; and good connections in Russia, will consider a proposition from manufacturing or consulting engineering concern desirous of developing Russian business. Available September 15.

782. An experienced teacher of electrical engineering desires position with larger opportunities for advancement. Laboratory specialist. At present acting director in middle western school. Consulting utility engineer. Age 29; married.

783. Electrical Technical graduate, age 25. Five years' practical experience, mostly power plant and substation installations. Desires position with lighting or power company, commercial end preferred, with good chance for advancement. Location no object; willing to travel. Detailed information furnished on request.

784. Mechanical and Electrical Engineer, 32, technical graduate; at present engineer for a company manufacturing special electrical and mechanical apparatus. Has had considerable experience in design and estimating, and in administrative work. Would accept position as engineer with a manufacturing or engineering company. Salary expected, $2400. Married.

785. Statistical Operating Electrical Engineer. Technical graduate. Capable of organizing or taking full charge of statistical department. Experience attained with large holding public utilities corporations. Salary $3000.

Digitized by Google

786. Professor of Electrical Engineering, with valuable commercial, engineering and teaching experience, is available for an appointment that offers good opportunities. Author of two successful textbooks. Available immediately.

787. Electrician and draftsman, 33, desires situation, preferably in West. High school and correspondence school education; also individual study. Four years in large hydroelectric stations; eighteen months in railway signal work; five years drafting in electrochemical concern and for large central station company. American.

788. Mechanical and Electrical Engineer, 36, technical graduate; fifteen years' experience in design, construction, operation of power plants and lines, water works and mains, would consider position as mechanical engineer or as superintendent. Permanent position only considered.

789. Technical Graduate, (M. E., 1917, with machine shop and automobile experience, desires position in power plant economy, testing department or similar line, in or near New York City. Hard worker; willing and adaptable. Age 22.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1916-1917.

PRESIDENT.
(Term expires July 31, 1917)
H. W. BUCK

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1917)
PAUL M. LINCOLN

(Term expires July 31, 1918)
JOHN J. CARTY

VICE-PRESIDENTS.

(Term expires July 31, 1917)
C. A. ADAMS
J. FRANKLIN STEVENS
WILLIAM McCLELLAN

(Term expires July 31, 1918)
B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON

MANAGERS.

(Term expires July 31, 1917)
FREDERICK BEDELL
BANCROFT GHERARDI
A. S. McALLISTER
JOHN H. FINNEY

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS

TREASURER (Term expires July 31, 1917)
GEORGE A. HAMILTON

SECRETARY.
F. L. HUTCHINSON

HONORARY SECRETARY.
RALPH W. POPE

LIBRARIAN.
HARRISON W. CRAVER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1916.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4
JOHN W. LIEB, 1904-5
SCHUYLER SKAATS WHEELER, 1905-6
SAMUEL SHELDON, 1906-7
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to July 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

H. W. Buck, Chairman,
49 Wall Street, New York.

N. A. Carle,	George A. Hamilton,
John H. Finney,	William McClellan,
Bancroft Gherardi,	J. Franklin Stevens.

FINANCE COMMITTEE.

J. Franklin Stevens, Chairman,
1326 Chestnut Street, Philadelphia, Pa.

N. A. Carle,	Bancroft Gherardi.

MEETINGS AND PAPERS COMMITTEE.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary, W. E. and M. Co. East Pittsburgh, Pa.

Frederick Bedell,	F. W. Peek, Jr.
Philander Betts,	F. L. Rhodes,
H. H. Clark,	D. W. Roper,
J. G. De Remer,	Harris J. Ryan,
H. A. Hornor,	T. H. Schoepf
Edward P. Hyde,	Charles P. Steinmetz,
L. E. Imlay,	N. W. Storer,
E. H. Martindale,	Wilfred Sykes.

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.

Frederick Bedell,	L. T. Robinson,
M. G. Lloyd,	C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
763 Broad Street, Newark, N. J.

J. C. Forsyth,	H. R. Sargent,
H. B. Gear,	G. A. Sawin,
A. H. Griswold,	A. M. Schoen,
H. O. Lacount,	George F. Sever,
Johnston Livingston,	C. E. Skinner,
Henry N. Muller	H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 W. 23rd Street, New York.

E. B. Katte,	W. I. Slichter,
F. L. Rhodes,	Philip Torchio.

SECTIONS COMMITTEE.

W. A. Hall, Chairman,
General Electric Company, West Lynn, Mass.

J. G. De Remer,	A. M. Schoen,
Paul M. Lincoln,	J. H. Tracy,

and the chairmen of all Institute Sections, *ex-officio*.

MEMBERSHIP COMMITTEE.

Harold Goodwin, Jr., Chairman,
1000 Chestnut Street, Philadelphia, Pa.

G. M. Baker,	W. G. Chace,
S. H. Blake,	H. W. Flashman,

E. H. Martindale.

and the chairmen of the Membership Committees of all Sections.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
165 Broadway, New York.

E. A. Carolan,	A. M. Hunt,
John J. Carty,	William McClellan,
Fredk. Darlington,	H. H. Porter,
Gano Dunn,	C. S. Ruffner,
John B. Fisken,	A. M. Schoen,

L. B. Stillwell,

COMMITTEE ON DEVELOPMENT OF WATER POWER

John H. Finney, Chairman,
509 Metropolitan Bank Building, Washington, D. C.

F. O. Blackwell,	Nicholas S. Hill, Jr.,
Francis Blossom,	E. A. Lof,
Gano Dunn,	W. V. N. Powelson,

L. B. Stillwell.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.

P. G. Agnew,	H. M. Hobart,
Frederick Bedell,	H. D. James,
Joseph Bijur,	P. Junkersfeld,
L. F. Blume,	A. E. Kennelly,
James Burke,	G. L. Knight,
G. A. Burnham,	A. S. McAllister,
N. A. Carle,	W. M. McConahey,
E. J. Cheney,	W. L. Merrill,
H. H. Clark,	Charles Robbins,
E. H. Colpitts,	L. T. Robinson,
F. P. Cox,	C. H. Sharp,
W. A. Del Mar,	C. E. Skinner,
E. J. Edwards,	A. J. Slade,
H. W. Fisher,	N. W. Storer,
W. S. Gorsuch,	R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau Street, New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.

C. A. Adams,	M. I. Pupin,
B. A. Behrend,	E. B. Rosa,
Louis Bell,	Charles F. Scott,
James Burke,	Clayton H. Sharp,
John J. Carty,	Samuel Sheldon,
Gano Dunn,	C. E. Skinner,
H. M. Hobart,	Charles P. Steinmetz,
John W. Lieb,	Elihu Thomson,
R. B. Owens,	Philip Torchio.

PATENT COMMITTEE.

Ralph D. Mershon, Chairman,
80 Maiden Lane, New York.

Bion J. Arnold,	Charles A. Terry,
John F. Kelly,	B. F. Wood,

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1917.
A. E. Kennelly, Chairman, Robert T. Lozier,
S. G. McMeen.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.
Charles F. Brush, N. W. Storer,
C. C. Chesney.

Term expires July 31, 1920.
Carl Hering, Harris J. Ryan.

Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1917.
B. A. Behrend, Paul M. Lincoln,
William McClellan.

Term expires July 31, 1918.
C. A. Adams, Harold Pender,
C. E. Skinner.

Ex-Officio.

H. W. Buck, President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to July 1, 1917.

POWER STATIONS.

J. G. De Remer, Chairman,
55 Liberty Street, New York.

J. M. Drabelle,	S. A. Moss,
C. C. Egbert,	R. J. S. Pigott,
W. S. Gorsuch,	Cecil Poole,
John Harisberger,	E. F. Scattergood,
A. H. Kruesi,	F. A. Scheffler,
Paul M. Lincoln,	W. R. Thompson,
Wynn Meredith,	Philip Torchio,
I. E. Moultrop,	H. L. Wallau,

B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Co., Niagara Falls, N. Y.

H. A. Barre,	P. M. Lincoln,
M. T. Crawford,	W. E. Mitchell,
E. E. F. Creighton,	G. J. Newton,
H. H. Dewey,	L. C. Nicholson,
P. M. Downing,	W. D. Peaslee,
H. W. Fisher,	Stefaan Pick,
F. A. Gaby,	C. S. Ruffner,
W. T. Goddard,	H. J. Ryan,
O. A. Havill,	F. D. Sampson,
R. F. Hayward,	H. E. Shedd,
J. P. Jollyman,	Julian C. Smith,

P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman.
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,	P. J. Kearny,
A. H. Babcock,	William McClellan,
Reinier Beeuwkes,	John Murphy,
E. J. Blair,	W. B. Potter,
L. P. Crecelius,	E. D. Priest,
J. V. B. Duer,	Charles H. Quinn,
George Gibbs,	Clarence Renshaw,
W. J. Harvie,	A. S. Richey,
Hugh Hazelton,	Charles F. Scott,
E. B. Katte,	John B. Taylor,

H. S. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Co., Cleveland, Ohio.

H. W. Cope,	G. A. Johnstone,
J. H. Davis,	C. A. Kelsey,
James Dixon,	C. L. Kennedy,
A. M. Dudley,	Charles D. Knight,
Herbert D. Dwight,	A. H. Lawton,
F. W. Ells,	A. M. MacCutcheon,
J. E. Fries,	A. G. Pierce,
F. R. Fishback,	James M. Smith,
R. H. Goodwillie,	H. Weichsel,
A. L. Hadley,	J. B. Wiard,

R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,	Richard C. Powell,
C. E. Clewell,	E. B. Rosa,
J. R. Cravath,	W. D'A. Ryan,
T. S. Perkins,	Clayton H. Sharp,

W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE.

Philander Betts, Chairman,
790 Broad Street, Newark, N. J.

Harold Almert,	A. H. Kruesi,
W. H. Blood, Jr.	William McClellan,
Fred A. Bryan,	Norman C. McPherson,
C. L. Cory,	Allard Smith,
Harry Clifford Eddy,	W. G. Vincent,
W. B. Jackson,	George W. Wittemore,

Clifton. W. Wilder

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
72 W. Adams St., Chicago, Ill .

L. L. Elden,	A. A. Meyer,
G. Faccioli,	L. C. Nicholson,
V. E. Goodwin,	N. L. Pollard,
E. M. Hewlett,	S. D. Sprong,
Paul M. Lincoln,	Philip Torchio,

H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTROMETALLURGY.

T. H. Schoepf, Chairman,
W. E. and M. Co., East Pittsburgh, Pa.

Wesley J. Beck,	F. G. Liljenroth,
F. A. J. Fitzgerald,	Eugene F. Roeber,
A. F. Ganz,	J. A. Seede,
F. A. Lidbury,	R. Tencher.

ELECTROPHYSICS.

F. W. Peek, Jr., Chairman,
General Electric Company, Pittsfield, Mass.

Frederick Bedell,	E. B. Rosa,
A. C. Crehore,	Harris J. Ryan,
G. Faccioli,	Clayton H. Sharp,
C. L. Fortescue,	C. P. Steinmetz,
W. S. Franklin,	P. H. Thomas,
A. E. Kennelly,	J. B. Whitehead.

TELEGRAPHY AND TELEPHONY.

F. L. Rhodes, Chairman,
195 Broadway, New York.

E. F. W. Alexanderson,	Kempster B. Miller,
R. E. Chetwood,	H. Mouradian,
M. M. Davis,	W. O. Pennell,
C. L. Fortescue,	Allard Smith,
H. M. Friendly,	John S. Stone,
F. B. Jewett,	John B. Taylor,
S. M. Kintner,	J. L. Wayne, 3rd
Wm. Maver, Jr.,	G. M. Yorke,

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th & Chestnut Sts., Philadelphia, Pa.
D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,	Guy Hill,
M. W. Day,	O. P. Loomis,
G. E. Edgar,	G. A. Pierce, Jr.,
W. L. R. Emmet,	H. M. Southgate,
W. R. Furlong,	E. A. Sperry,
H. L. Hibbard,	Wilfred Sykes,

F. W. Wood.

COMMITTEE ON USE OF ELECTRICITY IN MINES

H. H. Clark, Chairman,
U. S. Bureau of Mines,
40th & Butler Streets, Pittsburgh, Pa.

Frank E. Alexander,	L. C. Ilsley,
Frank H. Armstrong,	R. L. Kingsland,
Graham Bright,	Charles Legrand,
W. A. Chandler,	Charles M. Means,
F. J. Duffy,	K. A. Pauly,

H. M. Warren.

IRON AND STEEL INDUSTRY.

Wilfred Sykes, Chairman,
Box 242, East Liberty, Pa.

S. C. Coey,	A. G. Pierce,
F. B. Crosby,	J. C. Reed,
E. Friedlaender,	R. Tencher,
E. S. Jeffries,	Brent Wiley,
D. M. Petty,	R. B. Williamson

J. H. Wilson.

EDUCATIONAL COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.

Alexander Gray,	William McClellan,
E. J. Henkhe,	Chester W. Rice,
E. A. Loew,	C. E. Skinner

R. D. Thomson.

Digitized by Google

SPECIAL COMMITTEES.

Revised to July 1, 1917.

REORGANIZATION OF TECHNICAL COMMITTEES.

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N.Y.
F. L. Hutchinson, H. H. Norris,
A. S. McAllister, J. Franklin Stevens,
N. W. Storer.

COMMITTEE ON STUDENT BRANCHES.

C. W. Green, Chairman,
Massachusetts Institute of Technology,
Cambridge, Mass.
Alexander Gray, E. A. Loew,
C. Francis Harding, W. S. Rodman,
C. P. Scott.

COMMITTEE ON NATIONAL DEFENSE

John H. Finney, Chairman,
509 Metropolitan Bank Building,
Washington, D. C.

F. C. Bates, Secretary,
30 Church Street, New York.

B. J. Arnold, D. C. Jackson,
A. H. Babcock, John W. Lieb,
Philander Betts, P. M. Lincoln,
H. W. Buck, Ralph D. Mershon,
J. H. Cuntz, A. M. Schoen,
J. J. Carty J. Franklin Stevens.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, John F. Kelly,
Gano Dunn, A. S. McAllister,
Schuyler Skaats Wheeler.

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

C. O. Mailloux, John J. Carty.
Paul M. Lincoln, H. W. Buck

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

W. I. Slichter, Edward D. Adams,
Harold Pender, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

W. S. Franklin, G. W. Pierce.

ON ENGINEERING COUNCIL.

H. W. Buck, N. A. Carle,
E. W. Rice, Jr., P. Junkersfeld,
C. E. Skinner.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney, Charles W. Stone.
Calvert Townley.

ON JOINT COMMITTEE ON METRIC SYSTEM.

A. E. Kennelly,

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

COMMITTEE ON GENERAL ENGINEERING. ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand,
T. P. Strickland, N. S. W. Government Railways, Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
Richard O. Heinrich, Genest-str. 5, Schoeneberg, Berlin, Germany.
A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E., France.
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to July, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	H.E.Bussey,3d Nat. Bk. Bldg.Atlanta,Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	Geo. A. Burnham	Ira M.Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Taliaferro Milton	W. J. Crumpton, 111 W. Monroe St., Chicago, Ill.
Cleveland.....Sept. 27, '07	E. W. P. Smith	Bruce W. David, Lincoln Electric Co., Cleveland, Ohio.
Denver.....May 18, '15	H. S. Sands	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	A. A. Meyer	A. Oakes, 433 W. Forest Ave., Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Union Tel. Co. Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	William Deans, Franklin Hall, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	A. A. Thompson	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11		
Madison.....Jan. 8, '09	F. A. Kartak	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	F. W. Ells	H. P. Reed, Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Minnesota.....Apr. 7. '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	Earl J. Atkisson.	C. W. Markham, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	H. P. Liversidge	W. F. James, 14th Floor, Widener Bldg., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	G. C. Hecker	F. E. Wynne, W. E. and M. Company, East Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	L. T. Merwin	J. C. Martin, 1220 Spalding Bldg., Portland, Oregon.
Rochester.....Oct. 9, '14	O. W. Bodler	J. W. Morrison, Rochester Telephone Co., Rochester N. Y.
St. Louis.....Jan. 14, '03	A.McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	C. E. Eveleth	H. L. Andrews, General Electric Company Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	D. F. Henderson	C. M. Fisher, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	William G. Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb.
Urbana.....Nov. 25, '02	I. W. Fisk	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co., Vancouver, B. C.
Washington, D. C......Apr. 9, '03	Arthur Dunlop	Louis G. Freeman, U. S. Geological Survey, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	A. L. Wilson	W. L. Teague, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	Ralph H. Earle	Harold A. Kleinman, 7743 Burnham Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio.
Clarkson Col. of Tech...Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Charles C. Clymer	Victor E. Leroy, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ. of.....June 25, '14	D. Nankervis	L. J. Corbett, Univ. of Idaho, Moscow, Idaho.
Iowa State College....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col..Jan. 10, '08	R. H. Oliver	C. E. Reid, Kansas State Agri. Col., Manhattan, Kansas.
Kansas, Univ. of.....Mar. 18, '08	R. W. Davis	Clark Davis, University of Kansas, Lawrence, Kansas.
Kentucky, State Univ. ofOct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Samuel McC. Hunt	Carl Theodore Mack, 418 McCartney Street, Easton, Pa.
Lehigh University.....Oct. 15, '02	F. L. Magee	J. F. Wentz, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine, Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech.....Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	A. N. Clarke	F. E. Richardson, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of...May 16, '16	Jesse L. Thompson	Donald P. Loye, 4216 Dupont Ave., South Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Carl Ladenburg	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr., and Mech. Arts.Feb. 11, '10	F. E. Coxe	F. J. Haight, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of.Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University, N. D.
Norwich University....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University..Dec. 20, '02	H. D. Bender	L. W. Birch, 138 Wheatland Avenue, Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of....Oct. 11, '12	H. M. Richards	R. E. Heffner, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly,	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst..Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terre Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of...Dec. 13, '07	D. M. Alexander	C. W. Cutler, 702 California St., Pullman, Wash.
Washington Univ.....Feb. 6, '04	Charles A. Lieber	R. W. MacDonald, Washington University, St. Louis, Mo.
Washington, Univ. of..Dec. 13, '12	A. Kalin	J. R. Himmelsbach, 4629 21st Avenue, Seattle, Wash.
West Virginia Univ....Nov. 13, '14	O. P. Joliffe	D. F. Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst...Mar. 25, '04	C. W. Kennedy	J. A. Blair, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School, New Haven, Conn.

Total 59

Digitized by Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI AUGUST, 1917 Number 8

FLORIDA ENGINEERING SOCIETY

A cordial invitation has been extended by the Florida Engineering Society to the members of the Institute to attend any of the meetings of that Society or any of its local branches.

Mr. J R. Benton, Gainesville, Fla., is Secretary of the Society.

PAST SECTION MEETINGS

Baltimore.—Election of officers for the coming year as follows—chairman, J. B. Whitehead; secretary-treasurer, L. M. Potts; executive committee, A. S. Loizeaux, A. T. Clark, W. H. Swift, R. C. Faught, F. A. Allner, C. G. Edwards, and H. B. Stabler.

Cleveland.—May 21, 1917, Electrical League, Hotel Statler. A banquet dinner was served, after which Mr. John B. Taylor gave an illustrated lecture on the subject of "Sound". Election of officers as follows;—C. N. Rakestraw, chairman; C. S. Ripley, secretary-treasurer; G. N. Lindstrom, chairman, Papers Committee; Board of Managers, L. P. Crecelius, J. H. Van Horn and R. B. Chillas. Attendance 48.

Denver.—June 16, Denver Athletic Club. Election of officers as follows:—Norman Read, chairman; Fred J. Rankin, vice-chairman; Robert B. Bonney, secretary-treasurer. Address by Mr. R. G. Griswold on "The Development of Gas versus Electricity for Domestic Uses". Chairman Sands spoke of Mr. D. C. McClure who has recently received a commission as First Lieutenant in the Engineering Reserve Corps. Attendance 20.

Detroit-Ann Arbor.—May 25, 1917, Detroit Engineering Society Rooms. Address by Prof. H. H. Higbie on "A-C. Transformers". Attendance 30.

Indianapolis-Lafayette.—June 22, 1917, Indianapolis. Illustrated lecture by Mr. J. W. Esterline on "Overcoming the Higher Costs of Labor, Supplies, Machinery and Fuel by Increased Efficiency". Attendance 25.

Kansas City.—May 31, 1917, Y. M. C. A. Paper: "Electrical Machinery Tests and Specifications Based on Modern Standards" by H. M. Hobart. Selection of Mr. W. F. Barnes to fill the vacancy left by A. A. Thompson, chairman, who has moved to Chicago. Attendance 12.

Milwaukee.—June 20, 1917, City Club. Annual dinner at which officers were elected as follows:—chairman, Arthur Simon; secretary, Soren H. Mortensen. Illustrated talk by Messrs. Harry Sloan and Alex. H. Luedicke on "The Development of a Modern Ice Plant". Meeting under auspices of local section of A. S. M. E. Attendance 75.

Panama.—May 27, 1917, Balboa Heights, C. Z. Election of officers as follows:— chairman, C. J. Embree; vice-chairman, E. D. Stillwell; secretary treasurer, W. F. Kleene; executive committee, E. S. Guild; H. W. Jacobsen, and R. D. Prescott. Captain T. H. Dillon gave an outline of the conditions under which an engineer regiment might

Digitized by Google

be formed on the Canal Zone. Attendance 27.

July 1, 1917, Balboa Heights. Papers: (1) "Inspection, Tests and Specifications for Lock Equipment" by C. J. Embree. (2) "Galvanic Action Between Metals, and Life Tests of Paints" by F. B. Coyle. Attendance 37.

Philadelphia.—May 14, Engineers Club. Paper: "Inductive Interference" by H. Mouradian. Attendance 85.

June 11, Engineers Club. Annual Dinner and election of officers. Short address by Messrs. G. S. Crampton, W. C. L. Eglin, J. F. Stevens, Paul Spencer, Lieutenant Josephs, U. S. R. C., and J. H. Tracy. Election of officers as follows:— chairman, Nathan Haward; secretary-treasurer, H. Mouradian; assistant treasurer, E. B. Trittle; managers, M. G. Kennedy, H. Goodwin, Jr., and W. F. James. Attendance 40.

Portland Section.—Election of officers as follows:—chairman, J. C. Martin; secretary-treasurer, E. D. Searing; board of directors, W. D. Scott and R. M. Boykin.

St. Louis.—June 6, 1917, Engineers Club Rooms. Address by Mr. C. E. Michel on "The Economics of the Electric Range". Attendance 51.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held on July 12, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

McGOVERN, WILLIAM R., Chief Engineer, Central Group of Bell Telephone Cos., Chicago, Ill.

To Grade of Member

ARTHUR, WILLIAM, Electric Railway Engineer, New Haven, Conn.

CHAPMAN, A. P., Sup. Power & Repairs Ludlow Manufacturing Associates, Ludlow, Mass.

DEAN, HAROLD C., Assistant to President, New York & Queens Electric Light & Power Co., Long Island City, N. Y.

HUCH, OTTO F., Engineer, with A. C. Wood, Philadelphia, Pa.

MARX, ROLAND G., Electrical Engineer, Palo Alto, Cal.

REES, HARRY P., Instructor in Power Plant Practise, Wentworth Institute, Boston, Mass.

ROSENBLATT, GIRARD B., Engineer in Charge, Mining Div., Westinghouse Electric & Mfg. Co., Salt Lake City, Utah.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1917.

Albrecht, G. M. (Member), Washington, D. C.
Allen, L. C., Parkersburg, W. Va.
Anthony, R. H., Boston, Mass.
Beall, J. C., Atlanta, Ga.
Binney E. A., St. Louis, Mo.
Chandler, W. W., Pawtucket, R. I.
Clothier, H. W., (Member), Hebburn-on-Tyne, England.
Fielding, C. H., Baltimore, Md.
Fiske, G. I., S. Boston, Mass.
Freret, A. L., (Member), Birmingham, Ala.
Groff, V. R., Holtwood, Pa.
Hall, N., Detroit, Mich.
Harris, J. B., Jr., Pittsburgh, Pa.
Henderson, R. M., Attalla, Ala.
Leavitt, A. J. (Member), Boston, Mass.
Peyinghaus, R., Walkerville, Ont.
Pflaum, R. J., Anaconda, Mont.
Pilliod, J. J. (Member), Chicago, Ill.
Pyles, R. M., Sao Paulo, Brazil

Digitized by Google

Richards, A. F. W., Manchester, England
Ricketts, S. F. (Member), Toronto, Ont.
Rohde, A. A., Metaline Falls, Wash.
Schwartz, W. B., Atlanta, Ga.
Slepian, J., E. Pittsburgh, Pa.
Stannard, J. L., Portland, Ore.
Steffelaar, J. M., The Hague, Holland
Stryker, B. (Member), Philadelphia, Pa.
Vogel, H. F., S. Bethlehem, Pa.
Total 28

ADDRESSES WANTED

Any reader knowing the present address of any of the following members is requested to communicate with the Secretary at 33 West 39th Street.

O. A. Darnell
(former address)
Avalon, Cal.

J. B. Entz
(former address)
The White Co.
Cleveland, Ohio.

Milan S. Mitrovitch
(former address)
Union Powder Co.
Parlin, N. J.

PERSONAL

MR. ROBERT W. ADAMS was elected President of the Providence Engineering Society at its recent annual meeting. He has been connected with the General Electric Company for the past nine years and is at present Manager of the Providence office.

MR. HAROLD V. BOZELL, for the past nine years professor of electrical engineering at the University of Oklahoma, and who has been spending the past year at Yale University on Sabbatical leave, has resigned the Oklahoma position to become assistant professor of electrical engineering in the Sheffield Scientific School of Yale University.

MR. LESTER W. W. MORROW, who has been associate professor of electrical engineering at the University of Oklahoma and acting head of the department the past year during Prof. Bozell's leave, has been made professor of electrical engineering and head of the department, succeeding Prof. Bozell.

MR. FRANK G. TAPPAN, formerly instructor in electrical engineering at Cornell University, has accepted a position as associate professor of electrical engineering at the University of Oklahoma, Norman, Okla.

MR. EDWIN L. CONNELL, for the past five years engineer in the motor department of the Wagner Electric Mfg. Co., has severed his connection with that company. He will be engaged in engineering work for the Van Dorn Electric Tool Co.

MR. C. A. MUDGE formerly with the United States Light and Heat Corp., Niagara Falls, N. Y., has severed his connection with that company and assumed the position of General Manager of the Electro Dynamic Company, Bayonne, N. J.

OBITUARY

ALBERT F. GANZ, Professor of Electrical Engineering at Stevens Institute of Technology, died in his 46th year on July 26, 1917. Prof. Ganz was born in Germany. He received his early education in N. Y. schools and then entered Stevens Institute, graduating in 1895 with degree of Mechanical Engineer. He was immediately appointed Instructor in applied Electricity at Stevens, became Assistant Professor in 1897 and received full professorship in 1902. In addition to his work at Stevens Prof. Ganz has been often engaged as expert to make commercial and scientific tests and reports. Prof Ganz was a Fellow of the A. I. E. E. and a Member of the A. S. M. E.

Digitized by Google

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From April 3d, to June 1, 1917)

Unless otherwise specified, books in this list have been donated by the publishers. The Society does not assume responsibility for any statements made. They are taken either from the preface or the text of the book.

MOTOR BOATS, HYDROPLANES, HYDRO-AEROPLANES.

Construction and Operation with Practical Notes on Propeller Calculation and Design, an Illustrated Manual of Self Instruction for Owners and Operators of Marine Gasoline Engines and Amateur Boat-Builders. By Thomas H. Russell with Revisions and Extensions by John B. Rathbun. Chic., Charles C. Thompson Co., 1917. 254 pp., 106 illus., 5x8 in., cloth, $1.

Practical, non-mathematical handbook. Directions for building motor-boats are given, together with information concerning the various available types of motors and detailed instruction for their installation and operation.

COMPRESSED AIR FOR THE METAL WORKER.

By Charles A. Hirschberg. N. Y., The Clark Book Co., 1917. 321 pp., 294 illus., 5x8 in., cloth, $3.

Describes the various purposes for which compressed air is used in power plants, foundries, machine shops, forge shops, etc. The various types of tools and machines are illustrated, as well as the commercial forms of air compressors. A compendium of present-day methods of utilizing compressed air, confined entirely to practice and omitting theory.

HIGH SPEED INTERNAL COMBUSTION ENGINES.

By Arthur W. Judge. N. Y., The Macmillan Co.; Lond., Whittaker & Co., 1916. 9+350 pp., 217 illus., 6x9 in., cloth, $5.50.

The author has collected and classified the available information, and presents it as briefly as possible. The work discusses the theory of high speed internal combustion engines, and the experimental results which have been obtained. Contents: The Thermodynamics of the internal combustion engine; The conditions occurring in actual engines; Pressures and Temperatures in internal combustion engines; Indicators and indicator diagrams; The mechanics of the high speed internal combustion engine; Engine balance.

THE WOOL INDUSTRY.

Commercial Problems of the American Woolen and Worsted Manufacture. By Paul T. Cherington. N. Y., Chic., Lond., A. W. Shaw Co., (copyright 1916) 16+261 pp., 5x8 in., cloth, $2.50.

The author's purpose has been to present the results of an examination of the industries producing woolen and worsted fabrics, approached from the side of their buying and selling problems. Omits other features of the industry, such as wool-growing, tariff relations, manufacturing technique, etc.

A TEXT BOOK ON BRICK PAVEMENTS.

By Clark R. Mandigo. Kansas City, Western Paving Brick Manufacturers Association, 1917. 126 pp., 42 illus., 5x8 in., cloth, $1.50.

Contents: Brick pavements; Highway economics; The sub-grade and the foundation; Manufacture of Brick; Paving problems; Appendix, Standard specifications.

Intended for municipal officers, commissioners and citizens as well as for city and county engineers and contractors. Descriptive rather than technical, but intended to give accurate information of interest to all concerned in road improvement.

IRRIGATION WORKS CONSTRUCTED BY THE UNITED STATES GOVERNMENT.

By Arthur Powell Davis. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 16+413 pp., 128 illus., 6x9 in., cloth, $4.50.

Contains engineering descriptions, with the necessary illustrations, of the various projects undertaken by the Reclamation Service. The projects described are the Salt River, the Yuma, the Orland, the Grand Valley, the Uncompahgre, the Boise, the Minidoka, the Huntley, the Lower Yellowstone, the North Platte, the Truckee-Carson, the Carlsbad, the Hondo, the Rio Grande, the Umatilla, the Klamath, the Belle Fourche, the Strawberry Valley, the Okanogan, the Yakima and the Shoshone. Intended for engineers and those interested in the development of arid lands.

A TEXT-BOOK OF INORGANIC CHEMISTRY.

Edited by J. Newton Friend. vol. VIII. The Halogens and Their Allies. By Geoffrey Martin and E. A. Dancaster. Lond., Charles Griffin & Co., Ltd., 1915. 18+337 pp., 30 illus., 1 tab., 6x9 in., cloth, $3. (gift of J. B. Lippincott.)

A concise general account of the chief chemical

Digitized by Google

and physical properties of fluorine, chlorine, bromine, iodine, and manganese, and their compounds. Describes the most important manufacturing operations briefly. The work does not attempt to be exhaustive, but is provided with very numerous references to original publications on the various phases of the subjects dealt with.

HEATONS' ANNUAL.

The Commercial Handbook of Canada and Boards of Trade Register 13th Year 1917. Toronto, Heaton's Agency, 1917. 518 pp., 5x7 in., cloth, $1.25.

Collects in one volume the information of value to merchants and manufacturers. Includes lists of government officials, customs brokers, banking towns, registration offices, shipping directions, etc. The customs tariff and a digest of customs law and regulation are given. The work also contains much general information on the resources of the country, a gazetteer of commercial towns and an economic bibliography of governmental reports, together with the usual tables.

THE POWER KINK BOOK.

Novel Ideas and Simple Devices for Meeting Emergencies in the Power Plant, Compiled from the Regular Issues of "Power". N. Y., Power, 1917. 146 pp., 147 illus., 6x9 in., boards, $1.75.

A collection of methods devised by power plant engine runners and machinists for making repairs, overcoming difficulties and preventing accidents. The methods are classified into appropriate groups and clearly illustrated by numerous drawings and sketches.

ARITHMETIC FOR ENGINEERS.

Including Simple Algebra, Mensuration, Logarithms, Graphs, and the Slide Rule. By Charles B. Clapham. (The D. U. Technical Series) N. Y., E. P. Dutton & Co., (preface 1916) 436 pp., 149 illus., 6x9 in., cloth, $3.

The author's object is to treat the subject with sufficient detail and enough engineering application to provide a truly practical treatise, omitting all subjects which have only academic interest.

CHEMICAL TESTS FOR MINERALS.

By Arthur J. Burdick. Beaumont, Cal., The Gateway Publishing Co., 1917. 93 pp., 5x8 in., cloth, $1.25.

Handbook of simple qualitative tests, intended to enable prospectors without chemical training to identify the various rocks and ores met with in the field.

PRACTICAL MARINE ENGINEERING.

For Marine Engineers and Students with Aids for Applicants for Marine Engineer's Licences. 4th ed. rev. & enl. By Captain C. W. Dyson. N. Y., Marine Engineering, 1917. 16+982 pp., 500 illus., 6x9 in., cloth, $6.

A simple and fairly complete treatise, intended for operative engineers, and hence paying especial attention to the construction, operation, management and care of marine machinery. The use of higher mathematics is avoided.

ARCHITECTURAL DRAWING AND LETTERING.

A Manual of Practical Instruction in the Art of Drafting and Lettering for Architectural Purposes, Including the Principles of Shading and Rendering and Practical Exercises in Design. Part I Architectural Drawing. By Frank A. Bourne and H. V. Von Holst. Part 2 Architectural Lettering. By Frank Choteau Brown. Chic., American Technical Society, 1917. 102+48 pp., 94 illus., 6x8 in., cloth, $1.50.

Elementary work presenting the art in logical manner.

BUILDING SUPERINTENDENCE FOR STEEL STRUCTURES.

A Practical Work on the Duties of a Building Superintendent for Steel-Frame Buildings and the Proper Methods of Handling the Materials and Construction. By Edgar S. Belden. Chic., American Technical Society, 1917. 95 pp., 24 illus., 2 pl., 5x8 in., cloth, $1.

Concise practical discussion of the problems which confront the superintendent of structural steel construction, and of the proper methods of meeting them.

ELECTRICAL MEASUREMENTS IN PRACTICE.

By Malcolm Farmer. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 12+359 pp., 230 illus., 6x9 in., $4.

Intended to present the subject in a simple practical manner, from the point of view of engineers actively engaged in making measurements, tests and investigations in the electrical industry. All classes of measurements ordinarily made in the laboratory or by the testing engineer are included.

THE PANAMA CANAL AND COMMERCE.

By Emory R. Johnson. N. Y. & Lond., D. Appleton & Co. 1916. 295 pp., 8 illus., 7 maps, 5x7 in., cloth, $2.

Explains the reasons for the building of the canal and discusses the use of the waterway by the commerce and shipping of the United States

Digitized by Google

and other countries. Intended for those engaged in shipping and other students of the canal in relation to commerce. A companion volume to Gorgas' "Sanitation in Panama" and Sibert and Stevens' "The Construction of the Canal".

ANNUAL CHEMICAL DIRECTORY OF THE UNITED STATES.

B. F. Lovelace, Editor. Baltimore, Williams & Wilkins Co., (copyright 1917). 305 pp., 6x9 in., cloth, $5.

First issue. Includes American manufacturers of and dealers in chemical apparatus and equipment; and professional chemical firms and laboratories. Lists of colleges offering instruction in chemistry, experiment stations, technical and scientific societies are given, also of Federal and state officials of dairying, foods, drugs, etc. Bibliographies of American and foreign journals and important books of the year, with a concise review of new happenings, devices, methods and appliances conclude the book.

LAWS OF PHYSICAL SCIENCE.

A Reference Book. By Edwin F. Northrup. Phila. & Lond., J. B. Lippincott Co., 1917. 210 pp., 5x8 in., leather, $2.

A summary of the general propositions underlying physical science and engineering, classified for convenience in consultation. Each law is accompanied by one or more references to more extended information.

A bibliography is included.

OUTLINE OF INDUSTRIAL CHEMISTRY.

A Text-Book for Students. By Frank Hall Thorp, with assistance in revision from Warren K. Lewis. 3d ed. rev. & enl. N. Y., The Macmillan Co., 1916. 25+665 pp., 137 illus., 6x9 in., cloth, $3.75.

The present edition of this well-known treatise has been thoroughly revised, many sections having been re-written and much obsolete matter replaced by new material. The modern concepts and theories of chemistry have been introduced whenever these promised to make clearer the phenomena involved.

ELECTRIC RAILWAY TRANSPORTATION.

By Henry W. Blake and Walter Jackson. N. Y., The McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Ltd., 1917. 7+487 pp., 120 illus., 6x9 in., cloth, $5.

The first book, the authors state, devoted to transportation methods and practice. Largely compiled to put in convenient form matter which has appeared in the transactions of the American Electric Railway Transportation and Traffic Association and the electric railway periodicals.

Contents: Organization and Definitions; Adjustment of Service to Traffic; Accelerating Traffic Movement along the Line; Accelerating Traffic Movement on the Car; Car Types in Relation to Traffic; City Timetables-Preliminaries; Interurban Schedules and Dispatching; Fares; Fare Collection Practices and Devices; Public Relations; Promotion of Passenger Traffic; Traffic Signs for Cars, Station and Road-Information for the Public; Competition; Freight and Express Business; Selection and Training of Men; Wages and Wage Agreements; Welfare Work; Discipline of Trainmen; Forms of Extra Pay.

THE LIFE OF ROBERT HARE.

An American Chemist (1781-1858). By Robert Fahs Smith, Provost of the University of Pennsylvania. Phila. & Lond., J. B. Lippincott Co., 1917. 508 pp., 1 por., 4 illus., 6x9 in., cloth, $5.

Assembles the labors of Robert Hare in such a form as to acquaint students of chemistry with him, and to show his title to an exalted place in history of chemistry in this country. Told largely by hitherto unpublished letters and documents collected from forgotten journals and pamphlets.

STORAGE BATTERIES SIMPLIFIED.

Operating Principles, Care and Industrial applications, a Complete, Non-technical but Authoritative Treatise Discussing the Development of the Modern Storage Battery, Outlining the Basic Operation of the Leading Types, also the Methods of Construction, Charging, Maintenance and Repair. All Practical Applications of Commercial Batteries are Shown and Described. By Victor W. Page. 208 pp., 89 illus., 5x8 in., cloth, $1.50.

Special Instructions for Care and Repair of Automobile Batteries and a Glossary of Terms are included.

PLAIN AND ORNAMENTAL FORGING.

By Ernest Schwarzkopf. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 10+267 pp., 228 illus., 5x8 in., $1.50.

Written to provide a really practical treatise on the theory and practice of art metal and blacksmith work, suitable for use as a text-book for beginners. Simple and detailed drawings illustrating each important operation are provided, together with full explanations. Intended especially for self-instruction. The author has had many years experience as a blacksmith and an instructor in forge work.

Digitized by Google

INTERBOROUGH FINANCE.

Present and Future with especial reference to conditions when the New Lines shall have been completed. Including Synopsis of the Financial Structure of Interborough Consolidated Corporation. N. Y., Van Emburgh & Atterbury, 1917. 69 pp., 2 maps, 2 diagrams, 6x9 in., leather.

Contents: Interborough Consolidated Corporation; Interborough Rapid Transit Company; New York Railways Company; Partnership Between Interborough and City of New York; Will the Interborough Earn its Preferentials?

MECHANICAL APPLIANCES, MECHANICAL MOVEMENTS AND NOVELTIES OF CONSTRUCTION.

By Gardner D. Hiscox. 4th ed., enl. N. Y., The Norman W. Henley Publishing Co., 1917. 396 pp., 1000 illus., 6x9 in., cloth, $3.

A companion volume to the author's "Mechanical Movements, Powers and Devices," in which the special requirements of various arts and manufacturers are considered, and more detailed explanations of the devices are given. Includes a chapter on perpetual motion, illustrating many types of perpetual motion machines.

ELLIOT'S WEIGHTS OF STEEL.

For Engineers, Architects, Contractors, Builders, Steel Manufacturers, and all Users of Rolled Steel. Computed by Thomas J. Elliot. Cleveland, The Penton Publishing Co, 1916. 662 pp., 6x9 in., leather, $20.

Given the weight of a lineal foot of any section of rolled steel, this book of tables enables one to find the weight of a single piece of any length without performing the operation of multiplication.

FIRE PREVENTION AND PROTECTION.

A Compilation of Insurance Regulations Covering Modern Restrictions on Hazards and Suggested Improvements in Building Construction and Fire Prevention and Extinguishment. 3d ed. Completely rev. By A. C. Hutson, Fire Protection Engineer. N. Y. & Chic., The Spectator Co., 1916. 7+777 pp., 126 illus., 3 pl., 5x7 in., leather, $4.25.

Written especially for merchants, manufacturers and underwriters, as a succinct presentation of the knowledge necessary to attain as complete protection as possible from fire. Covers all the suggested regulations of the National Board of Fire Underwriters and allied organizations.

BATTLE FIRE TRAINING.

By Capt. G. S. Turner and Capt. J. J. Fulmer. Menasha, Wis., George Banta Publishing Co., 294 pp., 47 illus., 4x7 in., cloth, $1.

Calls attention to the existing necessity for the adoption in our army of a uniform system of collective training in battle fire, and offers a system based upon the principles laid down in the manuals upon fire and fire tactics published by the War Department.

MODERN MILLING.

A Practical Manual on Milling Machines, Milling Accessories and Milling Operations. By Ernest Pull. N. Y., The Macmillan Co.; Lond., Whittaker & Co., 1917. 8+207 pp., 188 illus., 6x9 in., cloth, $3.

Universal and plain milling machines are described as well as several special types, and their use for indexing, gear cutting and other operations is explained. Includes a chapter on speeds and feeds.

STEAM TURBINES.

A Practical Work on the Development, Advantage and Disadvantages of the Steam Turbine; The Design, Selection, Operation, and Maintenance of Steam Turbine and Turbo-Generator Plants. By Walter S. Leland. Chic., American Technical Society, 1917. 137 pp., 116 illus., 6x8 in., cloth, $1.

Intended for those less interested in the finer points of steam turbine theory than in the results accomplished and the way in which they have been secured by the successful builders. Over one half of the book is devoted to descriptions of various commercial turbines.

MECHANICAL MOVEMENTS, POWERS AND DEVICES.

A Treatise Describing Mechanical Movements and Devices Used in Constructive and Operative Machinery and the Mechanical Arts, Being Practically a Mechanical Dictionary, Commencing with a Rudimentary Description of the Early Known Mechanical Powers and Detailing the Various Motions, Appliances and Inventions Used in the Mechanical Arts to the Present Time. Including a chapter on Straight Line Movements. By Gardner D. Hiscox. N. Y., The Norman W. Henley Publishing Co., 1917. 409 pp., 1800 illus., 6x9 in., cloth, $3.

Digitized by Google

This edition is enlarged by the addition of over one hundred and sixty new mechanical movements and devices, and contains a total of sixteen hundred and sixty-five examples.

WATER PURIFICATION.

By Joseph W. Ellms. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10+485 pp., 149 illus., 6x9 in., cloth, $5.

Intended as a fairly complete account of the development of the art. Includes a consideration of the properties of various classes of waters and gives especial attention to the relation of polluted public water supplies to water-borne diseases. Describes in considerable detail the various steps in purification processes, such as sedimentation, coagulation, filtration and disinfection. Contains chapters on water softening and on the removal of iron and manganese from ground water supplies. Bibliographical references accompany each chapter.

TOPOGRAPHICAL DRAWING.

By Edwin R. Stuart. N. Y., McGraw-Hill Book Co., Inc., Lond., Hill Publishing Co., Ltd., 1917. 126 pp., 54 illus. 1 map, 6x9 in., cloth, $2.

Intended to furnish a satisfactory standard of practice in topographical drawing which will combine good execution with economy of time. Contents: Introductory; Map Projection; Instruments and Drawing Materials; Plotting; Special Methods in Free-Hand Drawing; Practice in Topographical Drawing; Lettering; Conventional Signs; Map Drawing.

MILITARY SKETCHING AND MAP READING.

By Capt. Loren C. Grieves. Wash., U. S. Infantry Assoc., 1917. 95 pp., 32 illus., 6x9 in., cloth, $1.

A text-book intended for officers of the National Guard, candidates for commissions in the Army and the Reserve Officers' Training Corps and for educational institutions. Meets the provisions prescribed by the War Department.

HOW TO STUDY.

By George Fillmore Swain. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10+65 pp., 5x7 in., paper, 25 cts.

Dr. Swain's little monograph is intended to formulate briefly and simply, certain fundamental principles of study and to point the way to proper habits and methods. Intended for students in and graduates of technical schools. Contents: Introduction; The Proper Mental Attitude; Studying Understandingly; System; Mental Initiative; Habits of Work; Suggestions to Teachers.

STATE SANITATION.

A Review of the Work of the Massachusetts State Board of Health. By George Chandler Whipple. Cambridge, Harvard University Press; Lond., Oxford University Press, 1917. 11+377 pp., 12 pl., 8 diagrams, 6x9 in., cloth, $2.50.

The first of a three-volume history, intended to set forth the past work of the Board, to reprint selected articles of importance from the older reports and abstracts of the others and to serve as an index and guide to the annual reports. Biographical sketches of the engineers, chemists and biologists of the Board will be included.

Volume one contains the history of the Board since its establishment in 1869, together with an abridged version of the "Report of the Massachusetts Sanitary Commission of 1850".

THE ESSENTIALS OF AMERICAN TIMBER LAW.

By J. P. Kinney. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 19+279+10 pp., 6x9 in., cloth, $3.

A presentation of the existing law regarding trees and their products as property, with such observations and references to historical development as are considered necessary to an understanding of the reasons for the law. Citations to the sections of the compiled or session laws of the different states enable the reader to find the various statutes in full. Especial prominence is given to interpretations of the law by the courts.

THE TAYLOR SYSTEM OF SCIENTIFIC MANAGEMENT.

By C. Bertrand Thompson. N. Y., Chic., Lond., A. W. Shaw Co., (copyright 1917) 175 pp., 22 illus., 5 diagrams, 9x11 in., flexible cloth, $10.

Intended to give, in addition to the history and theory of the system, enough development and operation to enable the factory manager to visualize the system in some detail, to distinguish clearly between it and other systems, and to understand its principles and mechanisms as found in actual practice. Based on personal investigations of all the installations of the system between Maine, Maryland and Chicago. Contains a bibliography of the important publications on the system.

FARM MOTORS.

Steam and Gas Engines, Hydraulic and Electric Motors, Traction Engines, Automobiles, Animal Motors, Windmills. By Audrey Potter. 2d ed. rev. & enl. (Agricultural Engineering Series) N. Y., McGraw-Hill Book Co., Inc.;

Digitized by Google

Lond., Hill Publishing Co., Ltd., 1917. 11+299 pp., 296 illus., 6x8 in., cloth, $1.50.

Includes the fundamental principles governing their construction, management and working. Intended for students of agricultural engineering and farmers. In the present edition the chapters on gas and oil engines and on traction engines have been enlarged, those on the steam engine rewritten, and chapters added on automobiles and animal motors.

APPLIED MECHANICS.

By Alfred Poorman. N. Y., McGraw Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 11+244 pp. 321 illus., 6x9 in., cloth, $2.

A text-book for undergraduate courses in engineering schools, in which the basic principles have been developed in a way which the average student can follow easily and illustrations showing clearly the application of such principles to the solution of engineering problems have been provided. Extended use has been made of the graphic method of solution.

PRINTING TRADES BLUE BOOK 1917.

N. Y. and Chic., A. F. Lewis & Co., 1917. 543 pp., 6x8 in., cloth, $3.

Directory of printers, dealers in paper machinery, metals, type, etc. in New York and surrounding towns. Arranged alphabetically, by telephone numbers and by classes. Includes directories of paper brands and of printing associations, unions and clubs.

WORKMEN'S COMPENSATION LAW.

Personal Injury by Accident Arising Out of and in the Course of the Employment. By P. Tecumseh Sherman. N. Y., Workmen's Compensation Publicity Bureau, (copyright 1916). 67 pp. 6x9 in., paper, $2.

A compilation of the decisions construing the British law on the subject, with abbreviated summaries of the relevant portions of the French and German laws. These precedents will be useful, the author believes, in defining the meaning of "accidents due to risk of work" as used in the American statutes.

ARTIFICIAL ELECTRIC LINES.

Their Theory, Mode of Construction and Uses. By A. E. Kennelly. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 348 pp., 117 illus., 6x9 in., cloth, $4. (gift of the author.)

Intended as a text-book for engineering-laboratory students and as a reference book for students of electric transmission in general. Based on the author's "The Application of Hyperbolic Functions to Electrical Engineering Problems". Restricted almost entirely to the phenomena of the steady state.

WINTER TRACK WORK.

By E. R. Lewis. Chic., Railway Educational Press, Inc. (copyright 1917) 166 pp., 21 illus., 5x8 in., cloth, $1.60.

Explains practical methods for maintaining railway track. Intended for use of trackmen. Contents: Climate and Track; Frost; Snow Shims and Shiming; Winter Track Force, Tools and Supplies; Snow Fences and Snow Sheds; Snow Handling Equipment; Spring Floods; Storing Ice; Organization.

A WONDERFUL FIFTY YEARS.

By Edwin T. Holmes. Privately published, (copyright 1917). 133 pp., 55 illus., 6x9 in., cloth, (gift of the author).

Personal reminiscences of the development of electrical communication from 1866 to 1916, during which time the author has been connected with the telegraph, telephone and electrical protective signaling industries of the country. Contains many interesting illustrations, reproductions of documents, and letters of historic interest.

COMPRESSED AIR PRACTICE IN MINING.

By David Penman, M. Inst. M. E. Phila., J. B. Lippincott Co.; Lond., Charles Griffin & Co., Ltd., 1917. 221 pp., 113 illus., 5x8 in., cloth,

Text book for use in mining schools, but also useful, it is hoped, to those in practice. Discusses air-compressors, methods of transmitting power and the use for compressed air for coal cutting, conveyors, drills, etc. A comparison of the advantages of compressed air and other means of transmitting power in mines is given.

STRESSES IN STRUCTURES.

By A. H. Heller. Rev. by Clyde T. Morris. 3d ed. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1916. 13+374 pp., 230 illus., 6x9 in., cloth, $2.75.

Author has attempted to provide a book which, without being an exhaustive scientific treatise on stresses, would be a suitable text-book for students and also a concise reference book for engineers. In the present edition various explanations have been expanded, numerical illustrative examples have been added and new material introduced where the reviser has found it necessary.

ELEMENTARY CHEMICAL MICROSCOPY.

By Emile Monnin Chamot. N. Y., John Wiley & Sons, Inc.; Lond., Chap-

Digitized by Google

man & Hall, Ltd., 1916. 13+410 pp., 147 illus., 6x9 in., cloth, $3.

The author believes that the American chemist has failed to appreciate the benefits to be obtained by the application of chemical microscopic methods in the industries and in research. This book is written to instruct him in the manipulation of the microscope and in the great variety of problems which may be solved by its use, and to call attention to the fields in which it is especially useful.

THE THEORY AND PRACTICE OF WORKING PLANS.

(Forest Organization) By A. B. Recknagel. 2d ed. rev. N. Y., John Wiley & Sons; Lond., Chapman & Hall, Ltd., 1917. 14+265 pp., 14 illus., 6 pl., 1 tab., 6x9 in., cloth, $2.

An adaptation of the best European efforts in forest organization to the present needs of American forestry, intended for the practicing forester as well as the student. The nomenclature of this edition has been revised in accordance with the suggestions of the Committee on Terminology of the Society of American Foresters, and the text as a whole has been revised and extended.

GRAY'S PLUMBING DESIGN AND INSTALLATION.

By William Beall Gray. N. Y., David Williams Co., 1916. 559 pp., 500 illus., 6x9 in., cloth, $4. (gift of U. P. C. Book Co.)

A reference work for plumbers, intended to illustrate fully standard American practice in all branches of the plumbing and allied trades.

HANDBOOK OF CHEMISTRY AND PHYSICS.

A Ready-Reference Pocket Book of Chemical and Physical Data. 5th ed. Cleveland, The Chemical Rubber Co.; 1917. 414 pp., 4x7 in., cloth, $2.

The present edition of this convenient reference book has been carefully revised, many new tables have been added and the index enlarged.

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-251. Good position open for capable young graduate of mechanical engineering with manufacturer of electric motors and generators, located in Middle West, as assistant to chief engineer. One to two years' experience essential. Only those whose services entitle them to advancement need apply. State age, salary expected, and date to enter duty.

V-252. Wanted by firm manufacturing electric motors and dynamos in Middle West, young electrical engineering graduate to enter sales department. Permanent position with good opportunity. Must be hustler and good correspondent; one with practical experience preferred. Answer, stating age, experience and salary expected.

V-254. Opportunity for a capable, live teacher of electrical engineering, in large Eastern university. Must be man of personality and good substantial training, and also with proven teaching ability. Good opportunity for development and advancement. Present position will pay from $1400 to $2000.

V-255. Wanted—Electrical Engineer with thorough knowledge of modern switchboard and switching practise for power stations and substations. Must be capable of handling large estimates and requisitions. Give full details of previous experience, salary expected, where at present employed. Apply—Works' Engineer, Canadian General Electric Co., Ltd., Peterboro, Ont.

V-256. Experienced motor salesmen for district offices in Chicago and

Digitized by Google

Kansas City. A splendid opportunity for live, experienced men on a line of a-c. and d-c. apparatus from 1 to 200 h.p. We operate on salary and bonus plan. State age, experience and salary record.

V-257. Electrical-Mechanical Engineer, with sufficient drafting experience to direct work in drafting department. Must have experience on a-c. and d-c. motor design; to work under chief engineer of exceptional ability, in Middle West. Factory manufacturing motors from ½ to 300 hp. The position offers excellent possibilities for the right man. State age, experience, and present salary.

V-258. Instructors in electric wiring and motor repair wanted by an electrical school in Brooklyn now training Army and Navy recruits. Thorough practical experience required and some teaching experience desirable. Beginning salary $100 to $150 per month, depending upon individual. Please give age, full particulars of education and experience, and recent photograph, if possible.

V-259. Electrical laboratory instructor wanted by technical school in Brooklyn now training Army and Navy recruits. Practical and teaching experience necessary and must be a graduate of engineering school. Beginning salary about $1500, depending upon individual. Apply by letter, giving age, full particulars of experience and education, and recent photograph if possible.

V-260. Electric railway in New York City wants young technical graduate to do general electrical engineering work, including calculations, estimates and sketches. Salary will depend upon qualifications. Applicants should give age, experience, salary desired, etc.

V-263. Instructors (1) in applied science laboratory and (2) in mechanics and elementary electricity wanted by a technical school in Brooklyn. Salary first year $1200 to $1500, according to individual. Preference given to men with mechanical or electrical engineering training and practical and teaching experience. State full personal and experience data, and enclose recent photograph, if possible.

The Illinois State Civil Service Commission announces that it will hold an unassembled examination for the position of electrical engineer for the Illinois Public Utilities Commission. Salary $200-$300 per month. Open to non-residents. Apply for blanks to the Illinois State Civil Service Commission at Springfield. No application forms will be mailed later than August 20.

MEN AVAILABLE

790. Electrical Engineer, married, at present employed; seven years experience in electrical power generation, transmission and distribution; wishes an executive position with small growing company offering chance of advancement to an efficient worker. Reason for desiring change, salary incommensurate with knowledge required and responsibilities imposed.

791. Are you searching for a young active technical man for manager or superintendent of small hydroelectric installation? Have had 11 years experience in power generation both in operating and semi-executive capacity. East or South preferred. Suggest that you permit writer to get in touch with you.

792. Mechanical-Electrical Engineer, Columbia graduate. Desires position as works engineer. Ten years' experience in industrial plant engineering, including installation and operation of power generating, transmission, and receiving apparatus. Also experienced in the application of electricity to shop processes, welding, electric heating, pyrometry, etc. Age 32. Married.

793. Engineering or Executive position desired. I am a university graduate in electrical engineering and post-graduate in mining engineering and electro-metallurgy. I have had twenty years experience in the manufacture, sale, installation and operation of electrical and mining machinery and have been a manufacturer's representative. Minimum salary $2400.

794. Are you in need of an electrical engineer with experience in the installation and maintenance of electrical apparatus for various purposes and familiar with general power plant practise? Prefer position in western part of U. S. Salary $1800.

795. Wanted—Position as public utility manager or on plant and substation construction. American, age 35, married, high-school and business college education, also I. C. S. electrical work. Fifteen years experience electrical work, and management of electric, gas, heating, and ice plants.

796. Executive Engineer desires position with industrial or public utility company. Graduate electrical engineer with broad experience as an executive and engineer with electric railway properties, power and lighting installations, and upon public utility valuations and industrial development. Available immediately.

Digitized by Google

797. Superintendent of Construction, finishing an extensive transmission line building program with no new work authorized, desires position as superintendent of moderate size light, power and gas company, or superintendent of service and distribution in large company. Long and successful experience. North Central States preferred. Age forty-three; married.

798. Graduate Electrical Engineer with four years operating and eight years designing experience, desires position with manufacturing or consulting engineering firm. At present employed as designing engineer by large electrical manufacturing company. Available immediately. Salary $3000. Age 36.

799. Russia.—Graduate mechanical and electrical engineer with eighteen years' broad business and technical training, (three years in Russia), desires responsible position with contracting or exporting concern of strong financial standing that is prepared for large business in Russia. Familiar with export organization; also construction and operation of all kinds of power plants.

800. Graduate Engineer, now superintendent of factory manufacturing large and small electrical machinery and transformers, will consider making a change. Eighteen years' experience in electrical, engine, and steel plate work. Familiar with up-to-date methods and systems. Least salary $7,500. Will consider part payment in stock of company.

801. Associate, with eighteen years' electrical experience desires position as chief electrician with industrial company. Excellent record on motor application, electrical construction and maintenance; high and low tension distribution. Employed at present but desires broader field.

802. Mechanical and Electrical Engineer. Experienced in design and construction of power plants, street railways and general engineering work in Australia and New Zealand. Has done a considerable amount of organization and administrative work. At present employed in U. S. by British government as inspector of munitions, but contracts are about completed. Present salary $5000.

803. Electrical and Mechanical Engineer, age 35, now employed in engineering department of large railroad company in the East, desires to make change. Would consider position as engineer for an industrial plant, or position with consulting engineering firm, engineering company, or holding company, as engineer to make investigations and reports on power plants, betterments to electrical central station systems, etc.

804. University of Michigan graduate, (1908), age 32, married, desires change of position. Experience—one year as operator (electrical) in large gas engine power house, and eight years in various positions in plant department of Am. Tel. & Tel. Co., with whom employed at present. Available on one month's notice to present employer.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1917-1918.

PRESIDENT.

(Term expires July 31, 1918)

E. W. RICE, Jr.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1918)
JOHN J. CARTY

(Term expires July 31, 1919)
H. W. BUCK

VICE-PRESIDENTS.

(Term expires July 31, 1918)

B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON
FREDERICK BEDELL
A. S. McALLISTER
JOHN H. FINNEY

MANAGERS.

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS
E. H. MARTINDALE

(Term expires July 31, 1921)
WALTER A. HALL
WILLIAM A. DEL MAR
WILFRED SYKES

TREASURER (Term expires July 31, 1918)
GEORGE A. HAMILTON

SECRETARY.
F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

LIBRARIAN
HARRISON W. CRAVER

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1917.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMPSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1892-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK 1916-17.

*Deceased.

Digitized by Google

LIST OF SECTIONS

Revised to August, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	Thomas C. Taliaferro, S. E. Underwriters Ass'n., Atlanta, Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	H. M. Hope	Ira M. Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Wm. J. Crumpton	C.A.Keller,Edison Building, Chicago, Ill.
Cleveland.....Sept. 27, '07	C. M. Rakestraw	C. S. Ripley, 711 Williamson Building, Cleveland, Ohio.
Denver.....May 18, '15	Norman Read	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	H. H. Higbie	H. J. Wyckoff, Detroit Edison Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne,Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Unoin Tel. Co., Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	V. Karapetoff (Acting Secretary), Cornell Univ., Ithaca, N. Y.
Kansas City, Mo.....Apr. 14, '16	W. F. Barnes	Glenn O. Brown, 5519 Tracy Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11		
Madison.....Jan. 8, '09	J. R. Price	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	Arthur Simon	Soren H. Mortensen, Allis-Chalmers Mfg. Co., West Allis, Wis.
Minnesota.....Apr. 7, '02	R. J. S. Carter	Vernon S. Beck, Beck Elec. Const. Co., Minneapolis, Minn.
Panama.....Oct. 10, '13	C. J. Embree	W. F. Kleene, Ancon, C. Z.
Philadelphia.....Feb. 18, '03	Nathan Hayward	H. Mouradian, Bell Telephone Co. of Penna., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	F. E. Wynne	G. M. Baker, G. E. Co., Oliver Building, Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	V. E. Goodwin	E. K. Shelton, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	J. C. Martin	E. D. Searing, 1185 Kerby Street, Portland, Oregon.
Rochester.....Oct. 9, '14	Frank C. Taylor	J. W. Morrison, Rochester Telephone Co., Rochester, N. Y.
St. Louis.....Jan. 14, '03	A.McR.Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	W. L. Upson	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	Charles A. Lund	Foster Russell, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, Cohen, Friedlander & Martin, Toledo, Ohio.
Toronto.....Sept. 30, '03	William G.Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb.
Urbana.....Nov. 25, '02	I. W. Fisk.....	L. V. James, Univ. of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian WestinghouseCo., Vancouver, B. C
Washington, D. C.....Apr. 9, '03	Paul G. Agnew	J. Ernest Smith, McKinley Manual Training School, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst.....Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	W. L. Teague	J. C. Douthit, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	E. A. Moore, Jr.	A. A. Hofgren, 7542 South Chicago Avenue, Chicago, Ill.
Brooklyn Poly. Inst.....Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio
Clarkson Col. of Tech....Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson AgriculturalCol.Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Robert Newman	William N. Gittings, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College.....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St.Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	L. N. Miller	M. H. Russell, Kansas State Agri. Col., Manhattan, Kansas.
Kansas Univ. of.....Mar. 18, '08	R. W. Davis	Clark Davis, University of Kansas, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron,State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Harry C. Hartung	William Lash Lipps, 633 Parsons, Easton, Pa.
Lehigh University.....Oct. 15, '02	R. H. Lindsay	R. D. Bean, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech.....Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	W. R. Harvey	T. W. Connant, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of.....May 16, '16	George W. Miller	Ray McKibben, University of Minnesota, Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col......May 21, '07	Roy C. Hagen	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr. and Mech. Arts..Feb. 11, '10	John R. Hauser	Landon C. Flournoy, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of. Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of..Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University ,N. D.
Norwich University.....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ.....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University...Dec. 20, '02	E. S. Gunn	T. D. Robb, 124 West 10th Ave., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col......Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	A. W. Watter	C. H. Whitwell, University of Oklahoma, Norman, Okla.
Oregon Agr. Col......Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College.....Dec. 20, '02	J. B. Kelly.	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terra Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker,Throop Dormitory,Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of.....Dec. 13, '07	S. Stites	E. Tollefson, State Coll. of Wash., Pullman, Wash.
Washington Univ.....Feb. 5, '04	Charles A. Lieber	R. W. Mac Donald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	L. P. Kongsted	L. M. Lubcke, University of Washington, Seattle, Wash.
West Virginia Univ......Nov. 13, '14	O. P. Jolifte	D. F Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	B. Luther	N. L. Towle, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School' New Haven, Conn.

Total 59

Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI SEPTEMBER, 1917 Number 9

INSTITUTE MEETING IN PHILADELPHIA OCTOBER 8, 1917

The 333d meeting of the A. I. E. E. will be held in Philadelphia, October 8, 1917. The general subject of the meeting will be Industrial Research. A discussion of industrial research should prove highly profitable and practical just at this time, when every energy is being focused on problems connected with the progress of a war, which, above everything else, is making use of every scientific advance.

Papers will be read by Mr. C. E. Skinner and Dr. F. B. Jewett, on the influence of industrial research on the development of electrical industries, and by Dr. A. E. Kennelly, on the contribution of Universities to industrial research. It is hoped to have a member of the National Research Council present to read a paper on the organizing of engineers, and engineering research in the prosecution of the war.

Afternoon and evening sessions will be held, and an informal dinner will take place between the sessions. The exact titles of the papers and the place of meeting will be announced later. There will be no New York meeting of the Institute in October.

A. I. E. E. DIRECTORS' MEETING AUGUST 14, 1917

The first meeting of the Board of Directors of the Institute for the administrative year beginning on August 1, 1917, was held at Institute headquarters, New York, on Tuesday, August 14, at 3 p.m.

There were present: President, E. W. Rice, Jr., Schenectady, N. Y.; Past-President, John J. Carty, New York; Vice-Presidents, B. A. Behrend, Boston, Mass., L. T. Robinson, Schenectady, N. Y., A. S. McAllister, New York; Managers, F. B. Jewett and William A. Del Mar, New York, John B. Taylor, Schenectady, N. Y., C. E. Skinner and Charles Robbins, Pittsburgh, Pa., N. A. Carle, Newark, N. J., E. H. Martindale, Cleveland, O., Walter A. Hall, West Lynn, Mass.; Treasurer, George A. Hamilton, Elizabeth, N. J.; Secretary, F. L. Hutchinson, New York.

President Rice announced the appointment in part of the committees for the administrative year. A complete list of these appointments is printed in this issue of the PROCEEDINGS.

The Patent Committee and the Committee on the Development of Water Power were not reappointed, it being felt that the functions of these two committees now come properly within the scope of the newly organized Engineering Council.

Mr. Guido Semenza was reappointed by the Board as Local Honorary Secretary for Italy for the term of two years ending July 31, 1919.

In accordance with the by-laws of the Edison Medal Committee, the Board elected from its own membership: John J. Carty, B. A. Behrend and A. S. McAllister to serve upon the committee for the term of two years, and L. T. Robinson to serve for one year to

Digitized by Google

fill the unexpired term of a retiring member of the Board of Directors.

The action of the Finance Committee in approving monthly bills amounting to $13,108.62 was ratified.

The report of the Board of Examiners of meetings held on July 12 and August 13 was read and the actions taken at those meetings were approved.

Upon the recommendation of the Board of Examiners

7 Students were ordered enrolled,
88 Applicants were elected to the grade of Associate,
6 Applicants were elected to the grade of Member,
19 Applicants were transferred to the grade of Member, and
2 Applicants were transferred to the grade of Fellow.

The program of Institute meetings for the coming year was discussed. It was voted to hold the October meeting in Philadelphia on October 8, and the November meeting in New York on November 9. Final decision regarding the balance of the program was deferred, with the understanding that the subject would be presented by the Meetings and Papers Committee for further consideration at the October meeting.

A considerable amount of other business was transacted by the Board, reference to which will be found in future issues of the PROCEEDINGS.

ENGINEERING COUNCIL.

Subsequent to the organization meeting held on June 27, 1917, the Engineering Council has held two other meetings, one on July 13 and on July 26. It has considered many matters of interest to engineers in general.

There have been appointed standing committees:

1. On Public Affairs, comprising Messrs. C. W. Baker, G. F. Swain, S. J. Jennings and E. W. Rice, Jr.

2. On Rules, comprising Messrs. J. P. Channing, Clemens Herschel, N. A. Carle and D. S. Jacobus.

3. On Finance, comprising Messrs. B. B. Thayer, I. E. Moultrop, Calvert Townley and Alex. C. Humphreys.

Many matters coming before the Council, both from the several founder societies and from the Council's predecessor, the Joint Conference Committee of National Engineering Societies, have been considered and referred to appropriate standing committees for investigation and report.

The Council has also created a War Inventions Committee comprising Messrs. H. W. Buck, A. M. Greene, Jr., and E. B. Kirkby, to cooperate with the Naval Advisory Board and other departments at Washington if desired in the promulgation to engineers of war problems now before the government and for which there are opportunities for solution by means of inventions. It also created a committee comprising Messrs. George J. Foran, E. B. Sturgis, A. S. McAllister and A. D. Flinn, which is to collect and compile such information regarding engineers of the country as will enable the committee to cooperate with the different departments of the Federal Government on request and to assist in supplying the Government's need for engineering services.

While the Council comprises only members from the four founder societies and of course can claim no right to speak for members of other societies nor for engineers at large, the Council members feel that the body will not have accomplished the results for which it was created unless it early establishes means of cordial cooperation with engineers, organized or otherwise. Every effort toward this end is contemplated.

PAST SECTION MEETINGS

Los Angeles.—May 29, 1917, Chamber of Commerce Building. Paper: "Insulators and Insulator Design" by C. P. Leibold.

Urbana.—June 8, 1917, Electrical Engineering Laboratory. Election of officers as follows: Chairman, L. V. James; secretary-treasurer, A. R. Knight.

Digitized by Google

ASSOCIATES ELECTED AUGUST 14, 1917

AUSTIN, B. O., Consulting Engineer, Charlotte; res., La Grange, N. C.

AVERBACH, JACOB EDWARD, Manager, Iron City Engineering Co., 1332 Dime Bank Bldg.; res., 99 Edmund Pl., Detroit, Mich.

AVERY, FLOYD B., Engineer, Wagner Electric Mfg. Co.; res., 6146 Suburban Ave., St. Louis, Mo.

*BADGER, HENRY STILLMAN, Assistant Division Inspector, Public Service Co. of Northern Illinois, Chicago Heights, Ill.

BAILEY, H. H., Resident Engineer, E. W. Clark & Co. Management Corp., Columbus, O.; res., 107 33rd Ave. S., Nashville, Tenn.

BLANCHARD, THEODORE STRONG, Y. M. C. A., Chester, Pa.

BOWLES, RICHARD HENRY, Assistant Electrical Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil, So. Amer.

BRIDGMAN, ARTHUR DWIGHT, Assistant Foreman, Switchboard Dept., Trumbull Electric Mfg. Co., Plainville, Conn.

BRODER, GEORGE A., Electrical Engineer, Erner Electric Co.; res., 2200 Prospect Ave., Cleveland, O.

*BROWN, ELMER ALFRED, Assistant Superintendent, Clark Mfg. Co.; res., 2318 E. 86th St., Cleveland, O.

*BUSH, GEORGE POLLOCK, 1st Lieutenant, Signal Corps, U. S. R., 1320 Consumers Bldg., Chicago, Ill.

CLAYTOR, EDWARD MCRAE, Designing Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 705 Lamar Ave., Wilkinsburg, Pa.

CLOVER, EMMETT BRANSON, Salesman, Economy Fuse & Mfg. Co., 1212 Majestic Bldg.; res., 624 Woodward Ave., Detroit, Mich.

COLLINS, ALVIN BATEMAN, Equipment Engineer's Assistant, Mountain States Tel. & Tel. Co.; res., 1053 Milwaukee St., Denver, Colo.

CONNELL, ROY, Principal Assistant Engineer, Hall Switch & Signal Co., Garwood; res., 171 Elm St., Westfield, N. J.

COVELL, RALPH A., Salesman, Cutler-Hammer Mfg. Co.; res., 125 W. Elm St., New Haven, Conn.

CREGAR, SAMUEL CLAY, Road Electrician, Union Pacific Railroad Co.; res., Fornam Hotel, Omaha, Neb.

CURTIS, HARRY ARTHUR, Power Station Supt., Hydroelectric Dept., Government of Tasmania, Hobart; res., Waddamana, Tasmania.

CUSHING, RICHARD WATSON, Junior Electrical Engineer, War Department, Engineer Depot, Washington Barracks, D. C.

DEHN, GEORGE R., Electrical Foreman, Panama Canal, Balboa, Canal Zone.

DEWITT, HENRY, Electrical Heating Engineer, Detroit Edison Co.; res., 642 Cadillac Ave., Detroit, Mich.

DIETERICH, FREDERICK C., Electrical Foreman, Construction Dept., Counties Gas & Electric Co.; res., 109 Stanbrige St., Norristown, Pa.

DILLON, THEODORE H., Captain Engineers, U. S. Army; Superintendent, Gatun Locks, Panama Canal, Gatun, Canal Zone.

DORSEY, OTIS BOND, Power Superintendent, Hopkins & Allen Arms Co.; res., 162 Broad St., Norwich, Conn.

EITZEN, LOUIS C., General Manager, August Mietz Corp., 128 Mott St., New York; res., 519 Lincoln Pl., Brooklyn, N. Y.

*ERICKSON, CARL JOSEPH, Engineer, Western Precipitation Co., 1016 W. 9th St., Los Angeles, Cal.

FLEISHER, WALTER ADLER, S. B. & B. W. Fleisher, Inc., 26th & Reed Sts.; res., 3422 Powelton Ave., Philadelphia, Pa.

FORNEY, ROSS HUBER, Chief Dispatcher, Texas Power & Light Co., 711 Interurban Bldg., Dallas, Tex.

FORSYTH, ARTHUR KENNARD, Engineering Dept., Western Electric Co.; res., 958 Anderson Ave., New York, N. Y.

Digitized by Google

FOURAKER, RAYMOND SPINEY, Designing Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 705 Lamar St., Wilkinsburg, Pa.

GRAVELL, JAMES HARVEY, Consulting Engineer, 149 Broadway, New York, N. Y.

GROENKE, GEORGE HERRMAN, Switchboard Operator, Miraflores Power Station, Panama Canal, Corozal; res., Ancon, Canal Zone.

HALE, WESLEY IVANHOE, Electric Inspector, E. I. du Pont de Nemours & Co., City Point; res., 402 S. 3rd St., Hopewell, Va.

HAMILTON, CLAUDE P., Foreman, Construction Dept., General Electric Co., Schenectady, N. Y.

HERRMANN, LEON CHARLES, Secretary and Electrical Engineer, Badt Westburg Electric Co., 832 Monadnock Block, Chicago, Ill.

HESS, VERNON E., Atchison, Topeka & Santa Fe Ry., Mechanical Bldg., Topeka, Kans.

HUTCHINGS, FRANK FARLEY, Engineering Dept., General Electric Co.; res., 15 Mall St., Lynn, Mass.

*JUNKINS, RAYMOND DEXTER, Testing Engineer, Pittsburgh Crucible Steel Co., Midland, Pa.

KING, A. B., Sales Manager, Electric Machinery Co.; res., 2639 Buchanan St. N. E., Minneapolis, Minn.

KING, ARTHUR ADDISON, Chief Electrician, Arizona Commercial Mining Co., Copper Hill, Ariz.

KIRKMAN, BERT, Electrician, Dept. of Parks, Borough of Brooklyn, New York City; res., 583 Eagle Ave., New York, N. Y.

LANDIS, CHARLES S., Operator, Engleside Substation, Edison Electric Co.; res., 21 Locust St., Lancaster, Pa.

*LANGSTAFF, HAROLD A. P., Electrical Engineer, Willis L. Adams, 311 Falls St., Niagara Falls, N. Y.

LEISENRING, FRANK SHEPPARD, Secretary, Wire Inspection Bureau; President, Mechanical Specialties Co., Park Row Bldg., New York, N. Y.

LITZEBAUER, FRED A., Estimator, E. S. Downs Co., 756 Broad St.; res., 877 S. 18th St., Newark, N. J.

LUCAS, BURTON E., Chief Electrician, Solvay Process Co.; res., 119 24th St., Detroit, Mich.

MCCHESNEY, ADELBERT BLOSS, Salesman, Crouse-Hinds Co., 30 Church St., New York, N. Y.; res., 244 Commonwealth Ave., Detroit. Mich.

*MCGREGOR, ANDREW JAMES, JR., Electrical Engineer, Public Service Commission, New York, N. Y.; res., 368 Palisade Ave., West Hoboken, N. J.

MCKENZIE, WILLIAM L., Manager, W. L. McKenzie & Co.; res., 1230 5th Ave. S., Lethbridge, Alta.

MEYER, HARRY V., Electrical Engineer, Harroun Motor Corp., Wayne; res., 130 Quincy Ave., Detroit, Mich.

*MOLITOR, FRED W., Electrical Laboratorian, U. S. Experiment Station, Naval Academy; res., 164 Green St., Annapolis, Md.

MURRELL, CLARENCE EDWARD, Assistant Field Engineer, Research Corporation, New York; res., 37 N. Pleasant Ave., Rockaway Beach, N. Y.

*NASH, EDWARD J., Electrical Engineer, Butte Electric Railway; res., 2031 S. Gaylord, Butte, Mont.

NICKEL, LEOPOLD W., Sales Engineer, Cutler-Hammer Mfg. Co., 50 Church St.; res., 516 W. 184th St., New York, N. Y.

NUKIYAMA, HEIICHI, Lecturer on Electrical Engineering, Tohoku Imperial University, Sendai, Japan.

OTTEN, HENRY, JR., Assistant Engineer, Economics Dept., Interborough Rapid Transit Co.; res., 761 Home St., New York, N. Y.

PECK, HENRY C., Lukens Iron & Steel Co., Coatesville, Pa.

PERRY, DANIEL WHITAKER, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 901 North Ave., Wilkinsburg, Pa.

PUTNAM, ROBERT G., Westinghouse Electric & Mfg. Co., E. Pittsburgh; res., 734 Wallace Ave., Wilkinsburg, Pa.

Digitized by Google

REID, ROBERT, Electrical (valuation) Engineer, Sierra and San Francisco Power Co., San Francisco; res., 1510 Ashby Ave., Berkeley, Cal.

ROUMBANIS, DEMETRIUS, Draftsman, Hydro-Electric Power Commission of Ontario, 190 University Ave., Toronto, Ont.

RYAN, FRANK EARL, Efficiency Engineer, Spokane Heat, Light & Power Co.; res., East 7, 28th Ave., Spokane, Wash.

RYAN, PAUL D., Electrical Engineer, U. S. Soldier's Home; res., 4010 Illinois Ave. N. W., Washington, D. C.

SALBERG, WILLIAM HARMON, Chief Electrician, Cleveland Crane & Engineering Co., Wickliffe, Ohio.

SALICIS, GEORGE A., Assistant Superintendent, Laurentide Power Co.,Grand Mere, P. Q., Canada.

SANFORD, SELDEN B., Engineer of Tests, Otis Elevator Co.; res., 526 W. 113th St., New York, N. Y.

*SCHLOTH, ARTHUR CARL, Turbine Test Dept., General Electric Co., W. Lynn, Mass.; res., 108 Kearsarge St., Manchester, N. H.

SCHULTZ, HERMAN WILLIAM, Electrical Engineer, Wm. C. Schultz & Son; res., 1102 Sixth St., Beloit, Wis.

*SHERRERD, GEORGE, JR., Commercial Engineer, Industrial Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

*SIMONICH, JOHN LAWRENCE, Engineer, Electric and Steam Test Dept., Pittsburgh Crucible Steel Co., Midland, Pa.

*SMILARI, MANLIO A., Designing Engineer, Transformer Engineering Dept., General Electric Co., Pittsfield, Mass.

SMITH, ARTHUR, Chief Electrical and Mechanical Engineer, Lacroze Tramway Co. Ltd., Buenos Aires, Argentine Republic, S. A.

SMITH, BERTRAND, Electrical Engineer, Arizona Power Co., Prescott, Ariz.

SMOLENS, HARRY, Inspector, Distribution Dept., Philadelphia Electric Co.; res., 3115 Columbia Ave., Philadelphia, Pa.

THOMPSON, CHARLES H., Motor Trouble Specialist, Cleveland Armature Works; res., 36 Brightwood St., E. Cleveland, O.

TINSON, HERBERT ARTHUR, Assistant Illuminating Engineer, Edison Lamp Works of General Electric Co., Harrison; res., 49 Dunnell Rd., Maplewood, N. J.

VAN STEENBERG, CHARLES F., Panama Canal, Pedro Miguel, Canal Zone.

WADE, WILLIAM HAMILTON, JR., Power Director, Norfolk & Western Railway Electrification, Bluestone; res., 605 Raleigh Terrace, Bluefield, W. Va.

*WALLACE, WILLIAM STINSON, Sales Engineer, Burke Electric Co.; res., 321 S. Evaline St., Pittsburgh, Pa.

*WARD, BUTLER E., 2nd Lieutenant, Corpsof Engineers, Co. No. 2, American University, Washington, D. C.

WELKE, RUDOLPH ALEXANDER, Cadet Engineer, New York Edison Co., New York; res., 28 Crescent Pl., Brooklyn, N. Y.

WHIPPLE, CHARLES L., Electrician, Anaconda Copper Mining Co.; res., 926 8th Ave. N., Great Falls, Mont.

WHITE, CUVIER W., 132 Penobscot St., Rumford, Me.

WHITNEY, WHEELOCK, St. Cloud Public Service Co., St. Cloud, Minn.

WILSON, ALFRED RANDOLPH, Secretary and Actuary, Amicable Life Insurance Co.; General Manager, Amicable Bldg., Waco, Tex.

WOLF, CLARENCE W. W., Construction Foreman, General Electric Co., Schenectady, N. Y.

WOOD, HARRY MENGER, Designing Engineer, Railway Engineering Dept., Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

YOKOYAMA, MASAJI, Engineer, Yokohama Electric Wire Works, No. 53, Ogawamachi, Kandaku, Tokio, Japan.

Total 88

*Former enrolled Students.

Digitized by Google

MEMBERS ELECTED AUGUST 14, 1917

FOLDS, GEORGE ROBERT, President, Frank B. Cook Co., 326 W. Madison St., Chicago, Ill.

FREEMAN, FREDERICK CHARLES, Construction Dept., United Gas Improvement Co., Philadelphia; res., 21 St. Pauls Rd., Ardmore, Pa.

KEITH, WILLIAM G., Commissioner Gas & Electricity, City of Chicago; res., 3755 N. Avers Ave., Chicago, Ill.

MOORE, R. W. E., General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

MORRIS, FREDERICK W., Chief of Testing Bureau, Electrical Engineering Dept., Brooklyn Edison Co., 360 Pearl St., Brooklyn, N. Y.

PIKE, ROBERT DICKSON, Chemical Engineer, 74 New Montgomery St., San Francisco, Cal.

TRANSFERRED TO THE GRADE OF FELLOW AUGUST 14, 1917

BLACKWELL, OTTO B., Transmission and Protection Engineer, American Telephone & Telegraph Co., New York, N. Y.

BLAKE, S. H., Engineer, Supply Dept., General Electric Co., Schenectady, N. Y.

CRAIGHEAD, JAMES R., Electrical Engineer, Standardizing Laboratory, General Electric Co., Schenectady, N. Y.

TRANSFERRED TO THE GRADE OF MEMBER AUGUST 14, 1917

ALEXANDER, HARRY, Electrical and Mechanical Contracting Engineer, New York, N. Y.

ANDRAE, ROBERT TURNER, Assistant General Manager, Northern Ontario Light & Power Co., Cobalt, Ont.

ATKISSON, E. J., Captain, Corps of Engineers, Assistant Superintendent, Gatun Locks, Gatun, C. Z.

AUTY, K. A., Sales Engineer, Commonwealth Edison Co., Chicago, Ill.

BAUHAN, ALEX. E., Station Superintendent, Pennsylvania Water & Power Co., Holtwood, Pa.

DAVIDSON, JAMES E., Assistant to the President, Omaha Electric Light & Power Co., Omaha, Neb.

DEXTER, HARRIS EDWARD, Engineer, Industrial Control Dept., General Electric Co., Schenectady, N. Y.

EALES, HERBERT W., Chief Electrical Engineer, Union Electric Light & Power Co., St. Louis, Mo.

GRAY, G. FRANCIS, Industrial Fellow, Mellon Institute of Industrial Research, Pittsburgh, Pa.

HALL, CHESTER I., Engineer, Demand Meter Dept., General Electric Co., Ft. Wayne, Ind.

JACKSON, NEWTON, Assistant to Electrical Engineer, United Gas Improvement Co., Philadelphia, Pa.

KELLER, C. A., Senior Engineer, Commonwealth Edison Co., Chicago, Ill.

LESLIE, EDWARD A., Electrical Engineer, New York, N. Y.

MURRAY, JOSEPH BRADLEY, Assistant General Manager, Edison Electric Illuminating Co. of Brooklyn, Brooklyn, N. Y.

PETTY, DAVID M., Superintendent, Electrical Dept., Bethlehem Steel Co., Bethlehem, Pa.

REYNEAU, P. O., Distribution Engineer, Detroit Edison Co., Detroit, Mich.

ROBERTS, T. C., Chief Engineer, United Verde Copper Co., United Verde & Pacific Railway Co., Clarkdale, Ariz.

WRAY, EDWARD, Assistant to General Manager, Sangamo Electric Co., Springfield, Ill.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its regular monthly meeting, held on August 13, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

BLISS, WILLIAM LORD, Chief Engineer, U. S. Light & Heat Corp., Niagara Falls, N. Y.

Digitized by Google

To Grade of Member

AGEE, HOWARD H., Engineer, D. C. & Wm. B. Jackson, Philadelphia, Pa.

DRABELLE, JOHN MITCHELL, Electrical Engineer, Iowa Railway & Light Co., Cedar Rapids, Ia.

FOX, MAURICE EDWARD, Chief Electrical Engineer, Edison Accumulators Ltd., London, England.

SMITH, HAROLD WHITMORE, Electrical Engineer, Dept. of Works & Railways, Commonwealth Government, Melbourne, Australia.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before September 30, 1917.

Anderson, C. A., Sydney, N. S.
Buck, A. M., Surf Inlet, B. C.
Coleman, J. E., Brooklyn, N. Y.
Connor, R. A., Chicago, Ill.
Eaton, R. M., Passaic, N. J.
Feder, J. B., New York, N. Y.
Garbutt, H. L., E. Pittsburgh, Pa.
Gibson, F. J., Philadelphia, Pa.
Hagan, J. S., East Pittsburgh, Pa.
Healy, E. S., Portland, Ore.
Jarrett, Le G., Bloomfield, N. J.
Kichlu, K. B., Highland Park, Mich.
Lardner, A. J., Christchurch, N. Z.
Lyons, E. J., Peoria, Ill.
McLaughlin, C. F., Little Rock, Ark.
Monteith, V. S., Hagerstown, Md.
Moore, S. E., St. Louis, Mo.
Persons, L. M., Chicago, Ill.
Schenck, S. B., E. Pittsburgh, Pa.
Shrader, W.M., Wappingers Falls, N. Y.
Smith, W. R. (Member), Sayville, N. Y.
Spencer, B. K., Chicago, Ill.
Stewart, C. C. (Member), Dewey, Okla.
Terwilliger, L. R., Rancagua, Chile
Tiffany, W. E., Albany, N. Y.
van der Bijl, H. J. (Member), New York, N. Y.
Walker, E. T., Washington, D. C.
Warden, R. M., City Point, Va.
Weiss, J., New York, N. Y.
Work, L., Philadelphia, Pa.
Worrall, R. H., Roselle, N. J.
Total 31.

STUDENTS ENROLLED AUGUST 14, 1917

9119 Jacobs, A. R., Univ. of Minn.
9120 Ellis, J. L., Jr., Ga. Sch. Tech.
9121 Crockett, T. W. D., Casino Tech. Night School.
9122 Luther, B., Worcester Poly. Inst.
9123 Payne, E. A., Colchester Tech. Coll.
9124 Ellwanger, E. C., Pratt Inst.
9125 Ellman, J. I., Drexel Institute.
Total 7

ADDRESSES WANTED

Any reader knowing the present address of any of the following members is requested to communicate with the Secretary at 33 West 39th Street.

Sydney J. Hurd
(former address)
4433 Prairie Ave.,
Chicago, Ill.

Wm. P. Lewis
(former address)
Cohoes Elec. Power Co.
Cohoes, N. Y.

Chas. E. Melvin
(former address)
U. S. S. *Severn*
c/o Postmaster,
New York, N. Y.

Milan S. Mitrovitch
(former address)
Union Powder Co.
Parlin, N. J.

Harrison W. Smith
(former address)
Mass Inst. of Tech.
Boston, Mass.

Digitized by Google

PERSONAL

Mr. EDWARD T. MOORE is at present with the Halcomb Steel Company, Syracuse, N. Y.

Mr. GEORGE E. A. FAIRLEY, principal engineer of the Municipal Electrical Commission of the City of Baltimore, has received a commission as Captain in the Engineer Corps of the U. S. Army.

Mr. JOHN A. SAMUELSON, for the past five years chief electrician for the Russell Water, Light and Power Company, has accepted a position as superintendent with the Hoxie Light and Power Company, at Hoxie, Kansas.

PROF. A. M. BUCK, for six years in charge of electric railway courses at the University of Illinois, has accepted a position with Mr. John A. Beeler, 52 Vanderbilt Avenue, New York. At present he is assisting Mr. Beeler in an investigation of the operations of the Boston Elevated Railway to determine if additional economies can be introduced. This investigation is being conducted for the Public Service Commission of Massachusetts.

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From July 15, to August 1, 1917)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made. These are taken either from the preface or the text of the book.

All the books listed may be consulted in the United Engineering Society Library.

AMERICAN HYDROELECTRIC PRACTISE. A Compilation of Useful Data and Information on the Design, Construction and Operation of Hydroelectric Systems from the Penstocks to Distribution Lines. By William T. Taylor and Daniel H. Braymer. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd.; 1917. 14+439 pp., 258 illus., 9x6 in., cloth, $5.

Not a text-book on the fundamentals underlying the design and construction of the parts of a hydroelectric system, but a compilation of the practical and essential features of design, construction and operation as used in many plants interpreted and arranged for use by designers, and engineers. Contents: General Survey of Water-Power Engineering; Low, Medium and High Head Developments; Layout and Selection of Plant Equipment; Transmission Line Construction and Operation; Plant Line and Substation Costs; System Operation and Economics; Special Plant and Line Problems; Data, Reference Tables and System Diagrams.

CHEMICAL DISCOVERY AND INVENTION IN THE TWENTIETH CENTURY. By Sir William A. Tilden. N. Y., E. P. Dutton & Co.; Lond., George Routledge and Sons, Ltd. (preface 1916) 16+487 pp., 150 illus., 11 por., 9x6 in., cloth, $3.50.

A semi-popular account of modern chemical discovery covering both theory and applications. Contents: Chemical Laboratories and the Work Done in Them; Modern Discoveries and Theories; Modern Applications of Chemistry; Modern Progress in Organic Chemistry.

CITY PLANNING PROGRESS. In the United States 1917. Compiled by the Committee on Town Planning of the American Institute of Architects. Edited by George B. Ford assisted by Ralph F. Warner. Washington, D. C., The Journal of the American Institute of Architects. 8+207 pp., 113 illus., 11x8 in., paper, $1.50.

A report on what has been accomplished or is projected in city planning in all cities in the United States of over twenty-five thousand inhabitants, and in a few cities and towns with a smaller population where the work is of special interest. Little attention has been devoted to housing, as a separate book on this subject is being prepared. Particular stress has been laid on the economic and engineering aspects of city planning.

The report is based on questions sent out by the committee, and includes only statements

Digitized by Google

from authentic printed reports or from those signed by responsible authorities in the respective communities.

COMPRESSED AIR.

Theory and Computations. By Elmo G. Harris. 2d ed., rev. and enl. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd. 1917. 15+192 pp., 32 illus., 9x6 in., cloth, $2.

Designed to present the mathematical treatment of the problems in the production and application of compressed air. In the present edition errors and ambiguities have been eliminated and new matter added.

EXPORT TRADE DIRECTORY 1917-1918.

Compiled by B. Olney Hough. N. Y., American Exporter, Johnston Export Publishing Co. 537 pp., 1 map, 9x6 in., cloth, $5.

Contents: Export Merchants in the United States; Manufacturers' Export Agents, Managers of Export Departments and Export Brokers; Leading Bankers Engaged in Foreign Exchange Business; Foreign Exchange Brokers; Marine Insurance Companies in New York City; Foreign Freight Forwarders; Some Export Trucking Companies in New York City; Steamship Services to Foreign Ports; How to Ship to Foreign Markets; Consuls of Foreign Countries in the United States; United States Consular and Commercial Representatives in Foreign Countries; Associations for the Promotion of Export Trade.

FARM CONCRETE.

By K. J. T. Ekblaw. N. Y., The Macmillan Co., 1917. 11+295 pp., 77 illus., 16 pl., 8x5 in., cloth, $1.60.

A simple, non-technical, yet reasonably comprehensive account of the methods of using concrete for farm buildings, fences, drains, bridges etc. Intended primarily for those without experience in the use of concrete.

GAS AND FUEL ANALYSIS FOR ENGINEERS.

A Compend for Those Interested in the Economical Application of Fuel. Prepared especially for the Use of Students at the Massachusetts Institute of Technology By Augustus H. Gill. 8th ed. rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 145 pp., 20 illus., 7x5 in., cloth, $1.25.

An attempt to present in a concise yet clear form the methods of gas and fuel analysis involved in testing the efficiency of a boiler plant. The directions for using the bomb calorimeter have been made to agree more closely with present usage in this edition, and minor corrections and additions have been made throughout the text.

GAS-LIGHTING AND GAS-FITTING.

A Pocket Book for Gas Companies, Gas Engineers and Gas Fitters, for Manufacturers of Gas Fixtures and Dealers in Gas Appliances, for Gas Consumers, Architects and Builders, Health Officers and Sanitary Inspectors. By Wm. Paul Gerhard. 4th ed. N. Y., D. Van Nostrand Co., 1913. Van Nostrand Science Series. 190 pp., 3 illus., 6x4 in., boards, 50 cts. (gift of the author and publisher.)

HOUSE-DRAINAGE AND SANITARY PLUMBING.

By Wm. Paul Gerhard. 12th ed. N. Y., D. Van Nostrand Co., 1907. Van Nostrand Science Series. 231 pp., 6 pl., 6x4 in., boards, 50 cts. (gift of the author and publisher.)

INTRODUCTION TO THE RARER ELEMENTS.

By Philip E. Browning. 4th ed. rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 10+250 pp., 6 illus., 1 pl., 9x6 in., cloth, $2.

The first edition of the book was prepared by the author from material used in a short lecture course at Yale University, as a convenient handbook in the introductory study of the rarer elements. Numerous changes and additions have been made in the present edition, in order to bring it up to date.

MACRAE'S BLUE BOOK.

America's Greatest Buying Guide. Vol. 8, 1917. Chic. and New York, MacRae's Blue Book Co. 1344 pp., 11x9 in., cloth, $10.

Contents: Catalogue Section; Address Section Representatives' Index; Classified Material Section; Comprehensive Trade Name Index; Miscellaneous Data Section; Standard List Prices of Building Materials and Iron and Steel Products; A Net Discount Computer.

NAVAL ARCHITECTURE.

By Cecil H. Peabody. 4th ed. rev. N. Y., John Wiley & Sons, Inc.; Lond.; Chapman & Hall, Ltd., 1917. 641 pp., 218 illus., 1 diagram, 9x6 in., cloth, $7.50.

Intended to give a consistent and connected statement of the commonly accepted theory of naval architecture. Intended for naval architects and shipbuilders, as well as for students.

Digitized by Google

Discussions of certain devices for checking rolling of ships, such as Frahm's anti-rolling tanks and the steadying gyroscopes of Schlick and Sperry, have been introduced in this edition.

OFFICE ORGANIZATION AND MANAGEMENT.

By Carl C. Parsons. Chic., LaSalle Extension University, 1917. 14+313 pp., 59 illus., 1 diagram, 8x6 in., leather, $2.50.

Treats of organization, management, layout, equipment, methods, systems, records, forms, employees, etc. Based on observation of the methods used in the offices of various large companies.

PAINT RESEARCHES AND THEIR PRACTICAL APPLICATION.

By Henry A. Gardner. Washington, D. C., (privately printed) 1917. 384 pp., 155 illus. 9x6 in., cloth, $5.

This volume is a summary of the author's investigations conducted at the Institute of Industrial Research for the Educational Bureau of the Paint Manufacturers' Association of the United States. Contents: The Growth of the Prepared Paint Industry and Its Relation to the Work of the Painter; The White Pigment Industry; Physical Characteristics of Pigments and Paints; Tests of Lithopone; Washington Paint Oil Tests; Paint Protection for Portland-Cement Surfaces; Paints to Prevent Electrolysis in Concrete Structures; Paints for Metal; Marine Paints; Arlington Paint Tests; Observations on Painted Lumber; Impregnated Panel Tests; Fire Retardent Paints for Shingles and Other Wooden Structures; The Composition of Paint Vapors; The Toxic and Antiseptic Properties of Paints; The Light-Reflecting Values of White and Colored Paints; Formation and Inhibition of Mildew in Paints; Fungi on Painted Surfaces; Changes Occurring in Oils and Paste Paints, Due to Autohydrolysis of the Glycerides; The Effect of Pigments upon the Constants of Linseed Oil; Storage Changes in Vegetable and Animal Oils; Paint Driers and Their Application; Miscellaneous Oil Investigations; The Application of Paints and Finishes to Wood.

PHOTOGRAPHY IN COLORS.

By George Lindsay Johnson. New and rev. ed. N. Y., E. P. Dutton & Co., 1917. 302 pp., 22 illus., 14 pl., 8x5 in., cloth, $2.

Intended to supply the information necessary for successful work, with any of the recognized methods of photography in colors. In this edition errors have been corrected, descriptions of the Raydex color process, of Gaumont's method of cinematography in colors and Carrara's method of reproducing autochromes on paper have been added, and chapters included on art in color photography and on photomicrography in color.

RAILWAY ESTIMATES.

Design, Quantities and Costs. By F. Lavis. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 12+608 pp., 99 illus., 9x6 in., cloth, $5.

A development of Chapter 8 of the author's "Railway Location, Surveys and Estimates," written to present in convenient form, data for the use of engineers called upon to: (1) Report on the value of, or estimate the probable cost of, proposed railways, either before or after surveys have been made; (2) Estimate the value of existing lines; (3) Design the general features of a proposed railway or modify the design of an existing line; (4) Determine the value or utility of such features of the general design of railways as affect their cost or value as transportation machines.

It is not intended to cover the design of details of structures, but rather to present sufficient data for the determination of both quantities and costs to aid, not only in the preparation of estimates, but also in the determination of the general features of design.

RECENT PRACTISE IN THE SANITARY DRAINAGE OF BUILDINGS.

With Memoranda on the Cost of Plumbing Work. By Wm. Paul Gerhard. 2d ed. rev. and enl. N. Y., D. Van Nostrand Co. 1890. D. Van Nostrand Science Series. 175 pp. 6x4 in., boards, 50 cts.

SANITATION PRACTICALLY APPLIED.

By Harold Bacon Wood. N. Y., John Wiley & Sons. Inc.; Lond., Chapman & Hall, Ltd., 1917. 473 pp., 44 illus., 8x5 in., cloth, $3.

This book serves as a corollary to treatises on the theory of hygiene and to laboratory manuals. It is intended primarily for the health officer and the student of public health topics, but the practical directions given are useful to all. Illustrations are introduced as explanatory of the text. Contents: The Need for Public Health Work; Statistics; The Control of Communicable Disease; Child Welfare; School Hygiene; Pure Foods; Clean Milk; Water Supplies; Sewage Disposal; Hygiene of the Home and Factory; The Destruction of Insects which Transmit Disease; The Educational Movement; Equivalents in Weights and Measures.

SHIPYARD PRACTICE AS APPLIED TO WARSHIP CONSTRUCTION.

By Neil J. McDermaid. 2d ed. N. Y. and Lond., Longmans, Green & Co.

Digitized by Google

1917. 332 pp., 153 illus., 9x6 in., cloth, $4.

A course of lectures given to Cadets of Naval Instruction at the Royal Naval College, Devonport. Describes the actual operations to be performed during the construction and outfitting of a warship.

STRENGTH OF MATERIALS.

By James E. Boyd. 2d ed. rev. and enl. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd. 1917. 16+380 pp., 254 illus., 9x6 in., cloth, $3.

No radical changes have been made in the present edition of this book. A chapter on Curved Beams and Hooks has been added and part of a chapter on Theories of Failure. The most important addition is the method of Area Moments for deriving the equations of the elastic line of beam. The book has been designed to be used in connection with either "Cambria Steel" or "Carnegie Pocket Companion".

THE DISPOSAL OF HOUSEHOLD WASTES.

By Wm. Paul Gerhard. 3d ed. N. Y. D. Van Nostrand Co., 1915 pp., 4 illus,. 6x4 in., boards, 50 cts.

A Discussion of the Best Methods of Treatment of the Sewage of Farm-Houses, Isolated Country Houses, Suburban Dwellings, Houses in Villages and Smaller Towns, and of Larger Institutions, such as Hospitals,Asylums, Hotels, Prisons, Colleges, etc., and of the Modes of Removal and Disposal of Garbage, Ashes, and other Solid House Refuse.

THE MODERN GAS TRACTOR.

By Victor W. Page. 2d ed. rev. and enl. N. Y., The Norman W. Henley Publishing Co., 1917, 32+504 pp., 225 illus., 7x5 in., cloth, $2.

Its Construction, Utility, Operation and Repair, A Practical Treatise Covering Every Branch of Up-to-Date Gas Tractor Engineering, Driving and Maintenance in a Non-Technical Manner, Considers Fully all Types of Power Plants and Their Components, Methods of Drive and Speed Changing Mechanisms, Describes Design and Construction of all Parts, Their Installation and Adjustment, as well as Practical Application of Tractors in the Field.

This treatise is intended to bridge the gap existing between the purely technical work and the manufacturers instruction book, dealing with one specific construction.

UNITED STATES ARTILLERY AMMUNITION.

3 to 6 in. Shrapnel Shells. 3 to 6 in. High Explosive Shells and Their Cartridge Cases. By Ethan Viall. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 98 pp., 171 illus., 12x9 in., cloth, $2.

This work is intended to give shop men, engineers and manufacturers an accurate knowledge of the sizes, tools, shop work and gages for the more commonly used United States shells and cartridge cases. The descriptions are in minute detail and accompanied by numerous dimensioned drawings.

WAR-SHIPS.

A Text-Book on the Construction, Protection, Stability, Turning, Etc. of War Vessels. By Edward L. Attwood. 6th ed. N. Y. and Lond., Longmans, Green and Co. 1917. 338 pp., 209 illus., 6x9 in., cloth, $4.

This book has been written in response to suggestions made by senior naval officers taking the course in Naval Architecture at the Royal Naval College Greenwich. An attempt has been made to treat the subject from the naval officers' standpoint and certain parts have been treated with a view of meeting their special requirements.

Digitized by Google

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-264. Position open for an experienced electrical engineer, about 30 years of age, with an established manufacturing concern. Must have fair knowledge of physics and chemistry. Excellent opportunity for the right man. State age, experience, salary expected, and give references.

V-265. Wanted: Electrical Draftsmen, Designers, and Engineers, on power station and substation layout work, combined with the electrical equipment of industrial plants, by organization doing work for U. S. Government. Exceptional opportunities for advancement. Salaries dependent on experience and ability of applicants.

V-266. Wanted: Recent technical graduate for general electrical engineering work with light and power company in New York City.

V-267. Capable and practical young electrical engineer to take charge of electrical equipment of shipbuilding organization. Give full particulars of past experience. Salary about $150 month to start.

V-268. The Georgia School of Technology has openings for an Associate Professor, and an Assistant Professor in Electrical Engineering. Good opportunities for advancement to right men. Give full information and references relating to character, habits, education and teaching experience.

V-270. Exceptional opportunities to mechanical engineers interested in modern power station work with rapidly growing company. Apply in person or by letter to Mr. J. M. Graves, Supt. Power Stations, Duquesne Light Co., Pittsburgh, Pa., giving your training experience, and class of work desired, whether operating, efficiency work, or designing.

V-271. Wanted: Capable and thoroughly experienced electrical engineer in both a-c. and d-c. design. One with plenty of mechanical knowledge that has been practically tested. One qualified to take charge of engineering department of concern located in Middle West. Answer stating age, past experience, salary and when open for position.

V-272. The Western Electric Company has opportunities for physicists, chemists, engineers and designers and draftsmen for work of research, development and design related to problems of telephonic, telegraphic and radio communication which are matters of public importance. Both temporary and permanent positions are open. Apply by letter, not in person unless so specifically requested, to F. B. Jewett, Chief Engineer, 463 West St., New York, N. Y.

MEN AVAILABLE

805. Experienced electrician, recent technical graduate, desires opening with reliable concern with chance for advancement. Eight years' experience on a-c. and d-c. power work.

806. Electrical Engineer, technical graduate, age 34, married. Ten years' experience with large hydroelectric companies in supervision, design, construction, operation and maintenance of power plants, substations, transmission lines and distributing systems. Also experienced in drafting, surveying, appraisal, etc. At present employed on construction.

807. Relay and meter man, eight years' practice. Capable of calculating short-circuit values and relay settings; familiar with oscillograph work and various kinds of power house and substation testings. Capable to repair and test all kinds of indicating, integrating and graphic meters. No traveling.

Digitized by Google

Married. Age 30. Technical education.

808. Sales Engineer desires position with large manufacturer as Eastern representative. Graduate of technical school, eight years' experience in the electrical industry. Would be willing to handle manufacturer's products on commission basis.

809. Graduate in electrical engineering, with several years' experience in central station work. Power, substation and switchboard designs, inspection, estimating, ordering of apparatus, supervision of work, etc. Wishes responsible position. At present engaged with electric light and power company.

810. Technical graduate with four years' experience in operation and maintenance of substations, steam and hydro plants; also A. H. I. business course, desires position where initiative and ability will bring promotion to responsible position. Age 24; single.

811. Electrical Engineer, at present in charge of engineering department of large Eastern power company; with eight years' experience in design of high and low tension overhead and underground lines, generating and substations; wishes executive position in a public utility or similar enterprise. Married.

812. Electrical Engineer, 1904 graduate, now teaching in a New York City college, has time available for outside research or consulting work. Would like to associate himself with an electrical engineer. Initial pay no object. Experience includes shop work, railroad signal installation, general electrical contracting and teaching of electrical engineering.

813. Electrical and Industrial Engineer, of ten years' construction, operating and designing experience on hydro-electric and steam generating plants, high and low tension transmission systems and substations, standard and special equipment for metal and electrochemical industries, is available shortly as designing engineer or for other responsible position.

814. Distribution Engineer, American, Mem. A. I. E. E. Ten years' experience in design, construction and maintenance of aerial and underground distribution systems. Thoroughly familiar with modern methods as applied to distribution problems; can handle work to advantage and familiar with all necessary records and plans required in this class of work.

815. University of Michigan graduate, 1913, wishes position in the engineering department or as district superintendent for a central station company, or with an electrical consulting engineering firm. Experience—four years of varied central station work and two years developing an electrical specialty. Age 26, married. Salary $150.

816. Engineer-Executive, desires position with industrial or public utility company. Age 35, American, married. Technical graduate, fifteen years' experience in engineering, operating and executive positions. Splendid record. Can handle men and produce results. Available at once.

817. Position as electrical engineer or assistant with established firm of consulting engineers, or would become member of new firm. Nine years' broad experience in testing, research work, designing and construction of power houses and substations, operation of high tension systems, rate making and business training. Age 31. Detroit vicinity preferred.

818. Development Engineer, particularly experienced in devising mechanical-electrical apparatus, standardizing and production, supervision of intricate machinery. Salary $2500.

819. Mechanical and Electrical Engineer, technical graduate, having six years' experience in shop, test, production, and now sales work with two large electrical manufacturers, wishes executive sales position with smaller firm promising large future and quicker advancement. Present salary $2600. At end of draft list. Married, 27, tactful, energetic and resourceful.

820. Superintendent of power for steam electric and compressor plant. Age 31, married, technical graduate. Seven years' experience in design, construction and operation of steam power plants and electric transmission lines. At present superintendent of 10,000 h.p. power plant for mining company in the Southwest.

821. Manager: technical and practical. Six years' experience as electrical engineer, commercial manager and executive with electric light, power and railway company. Experience covers design, construction and operation of distribution and transmission systems, intensive new business campaigns, commercial engineering, reorganization of utilities, valuation and rate hearings. Age 28, married. East preferred.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1917-1918.

PRESIDENT.

(Term expires July 31, 1918)

E. W. RICE, Jr.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1918)
JOHN J. CARTY

(Term expires July 31, 1919)
H. W. BUCK

VICE-PRESIDENTS.

(Term expires July 31, 1918)

B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON
FREDERICK BEDELL
A. S. McALLISTER
JOHN H. FINNEY

MANAGERS.

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS
E. H. MARTINDALE

(Term expires July 31, 1921)
WALTER A. HALL
WILLIAM A. DEL MAR
WILFRED SYKES

TREASURER (Term expires July 31, 1918)
GEORGE A. HAMILTON

SECRETARY.
F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

LIBRARIAN
HARRISON W. CRAVER

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1917.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1892-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK 1916-17.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to September 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

E. W. Rice, Jr., Chairman,
General Electric Company, Schenectady, N. Y.
H. W. Buck, Harold Pender,
N. A. Carle, L. T. Robinson,
George A. Hamilton, C. E. Skinner.

FINANCE COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
Walter A. Hall, Charles Robbins.

MEETINGS AND PAPERS COMMITTEE

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary,
Westinghouse E. and M. Company, Pittsburgh, Pa.
B. A. Behrend, Harris J. Ryan,
W. I. Slichter,
and the chairmen of the technical committees

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
M. G. Lloyd, L. T. Robinson,
Henry H. Norris, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
80 Park Place, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller, H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 West 23rd St., New York.
William McClellan, F. L. Rhodes,
Henry H. Norris, W. I. Slichter.

SECTIONS COMMITTEE.

Walter A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
P. H. Daggett, Vice-Chairman
John B. Fisken, H. W. Flashman,
A. M. Schoen,
and the chairman of all Institute Sections, *ex-officio.*

COMMITTEE ON STUDENT BRANCHES.

(Sub-Committee of Sections Committee.)
P. H. Daggett, Chairman,
University of North Carolina, Chapel Hill, N. C.
Alexander M. Gray, A. C. Lanier,
C. Francis Harding, Charles F. Scott.

MEMBERSHIP COMMITTEE.

H. A. Pratt, Chairman,
W. E. and M. Company, 165 Broadway, N. Y.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
W. E. and M. Company,
165 Broadway, New York.
H. W. Buck, P. Junkersfeld,
N. A. Carle, John W. Lieb,
John J. Carty, E. W. Rice, Jr.,
C. E. Skinner.

HEADQUARTERS COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
A. S. McAllister, F. L. Hutchinson.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, W. S. Gorsuch,
Frederick Bedell, F. C. Hanker,
Joseph Bijur, H. M. Hobart,
L. F. Blume, P. Junkersfeld,
James Burke, A. E. Kennelly,
G. A. Burnham, G. L. Knight,
N. A. Carle, F. A. Laws,
P. H. Chase, A. S. McAllister,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
William A. Del Mar, C. E. Skinner,
A. M. Dudley, N. W. Storer,
E. J. Edwards, John B. Taylor,
H. W. Fisher, R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau St., New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, A. S. McAllister,
B. A. Behrend, M. I. Pupin,
James Burke, E. B. Rosa,
John J. Carty, David B. Rushmore,
Gano Dunn, Charles F. Scott,
H. M. Hobart, Clayton H. Sharp,
John W. Lieb, C. E. Skinner,
Elihu Thomson.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, A. S. McAllister,
Gano Dunn, Schuyler Skaats Wheeler

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.
Term expires July 31, 1919.
Charles F. Brush, Chairman,
481 The Arcade, Cleveland, Ohio.
N. W. Storer, C. C. Chesney.
Term expires July 31, 1920.
Carl Hering, Harris J. Ryan,
Robert Lindsay.
Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.
Term expires July 31, 1922.
C. A. Adams, L. A. Ferguson,
S. W. Stratton.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1918.
L. T. Robinson, Harold Pender,
C. E. Skinner.
Term expires July 31, 1919.
B. A. Behrend, John J. Carty,
A. S. McAllister.
Ex-Officio.
E. W. Rice, Jr., President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to Leptember 1, 1917.

POWER STATIONS.

Philip Torchio, Chairman,
N. Y. Edison Company, 124 E. 15th St., New York.

L. P. Crecelius, H. S. Putnam,
W. S. Gorsuch, F. A. Scheffler,
P. M. Lincoln, R. F. Schuchardt,
S. A. Moss, H. L. Wallau,
I. E. Moultrop, W. F. Wells,
B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Company, Niagara Falls, N. Y.

A. O. Austin, P. M. Lincoln,
J. A. Brundige, L. C. Nicholson,
H. W. Buck, W. D. Peaslee,
Wallace S. Clark, D. W. Roper,
E. E. F. Creighton, Harris J. Ryan,
H. W. Fisher, P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman,
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams, William A. Del Mar,
A. H. Armstrong, J. V. B. Duer,
A. H. Babcock, John Murphy,
Reinier Beeuwkes, Charles F. Scott,
W. H. Blood, Jr., H. M. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Company, Cleveland, O.

H. W. Cope, Charles D. Knight,
James Dixon, A. M. MacCutcheon,
A. M. Dudley, A. G. Pierce,
R. H. Goodwillie, James M. Smith,
A. L. Hadley, H. Weichsel,
C. A. Kelsey, J. B. Wiard,
R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin, R. C. Powell,
C. E. Clewell, E. B. Rosa,
J. R. Cravath, W. D'A. Ryan,
Bassett Jones, Clayton H. Sharp,
T. S. Perkins, W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE

[Not yet appointed.]

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
Commonwealth Edison Company, 72 W. Adams St., Chicago, Ill.

E. E. F. Creighton, P. M. Lincoln,
Leslie N. Crichton, A. A. Meyer,
James C. Dow, N. L. Pollard,
L. L. Elden, F. E. Ricketts,
E. M. Hewlett, Philip Torchio,
H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

F. A. J. Fitzgerald, Chairman,
Fitzgerald Laboratories, Niagara Falls, N. Y.

Lawrence Addicks, F. A. Lidbury,
Joseph L. Dixon, T. H. Schoepf,
I. R. Edmands, J. A. Seede,
Carl Hering, Willis R. Whitney.

ELECTROPHYSICS.

[Not yet appointed.]

TELEGRAPHY AND TELEPHONY.

L. F. Morehouse, Chairman,
A. T. and T. Company, 195 Broadway, New York.

E. F. W. Alexanderson, William Maver,
R. E. Chetwood, Kempster B. Miller,
E. B. Craft, John Stone Stone,
M. M. Davis, John B. Taylor,
A. H. Griswold, J. L. Wayne.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.

D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr., Guy Hill,
M. W. Day, O. P. Loomis,
L. A. Doggett, G. A. Pierce, Jr.,
G. E. Edgar, H. M. Southgate,
W. L. R. Emmet, E. A. Sperry,
W. R. Furlong, Wilfred Sykes,
H. L. Hibbard, F. W. Wood.

USE OF ELECTRICITY IN MINES.

H. H. Clark, Chairman,
Bureau of Mines, 40th and Butler Sts., Pittsburgh, Pa.

Frank H. Armstrong, R. L. Kingsland,
Graham Bright, A. B. Kiser,
W. A. Chandler, Charles Legrand,
F. J. Duffy, Charles M. Means,
L. C. Ilsley, K. A. Pauly,
H. M. Warren,

ELECTRICAL MACHINERY.

Alexander M. Gray, Chairman,
Cornell University, Ithaca, N. Y.

B. A. Behrend, H. F. T. Erben,
A. M. Dudley R. B. Williamson,
James Burke.

INSTRUMENTS AND MEASUREMENTS.

S. G. Rhodes, Chairman,
104 East 32nd St., New York.

P. G. Agnew, F. V. Magalhaes,
F. P. Cox, T. S. Perkins,
Clayton H. Sharp.

IRON AND STEEL INDUSTRY.

F. D. Egan, Chairman,
Pittsburgh Crucible Steel Co.,
Midland, Pa.

EDUCATIONAL.

[Not yet appointed.]

Digitized by Google

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

C. O. Mailloux, John J. Carty.
Paul M. Lincoln, H. W. Buck.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

W. I. Slichter, Edward D. Adams,
Harold Pender, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

W. S. Franklin, G. W. Pierce.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney Charles W. Stone,
Calvert Townley.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON ENGINEERING COUNCIL.

H. W. Buck, N. A. Carle,
E. W. Rice, Jr., P. Junkersfeld,
C. E. Skinner.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

COMMITTEE ON GENERAL ENGINEERING, ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE.

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.

Robert Julian Scott, Christchurch, New Zealand

T. P. Strickland, N. S. W. Government Railways Sydney, N. S. W.

W. G. T. Goodman, Adelaide, South Australia.

James S. Fitzmaurice, Perth, West Australia.

L. A. Herdt, McGill Univ., Montreal, Que.

Henry Graftio, Petrograd, Russia.

A. S. Garfield, 45 Boulevard Beausejour Paris, 16 E. France.

Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.

John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to September, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	Thomas C. Taliaferro, S. E. Underwriters Ass'n., Atlanta, Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	H. M. Hope	Ira M. Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Wm. J. Crumpton	C.A.Keller,Edison Building, Chicago, Ill.
Cleveland.....Sept. 27, '07	C. M. Rakestraw	C. S. Ripley, 711 Williamson Building, Cleveland, Ohio.
Denver.....May 18, '15	Norman Read	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	H. H. Higbie	H. J. Wyckoff, Detroit Edison Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne,Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Unoin Tel. Co., Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	V. Karapetoff (Acting Secretary), Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	W. F- Barnes	W. F. Barnes, Kansas City, Mo.
Los Angeles.....May 19, '08	R. H. Manahan	Carl E. Johnson, 459 East Third Street, Los Angeles, Cal.
Lynn.....Aug. 22, '11	J. M. Davis	R. D. Thomson, General Electric Company, West Lynn, Mass.
Madison.....Jan. 8, '09	J. R. Price	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	Arthur Simon	Soren H. Mortensen, Allis-Chalmers Mfg. Co., West Allis, Wis.
Minnesota.....Apr. 7, '02	F. W. Springer	A. B. King, Electric Machinery Company, Minneapolis, Minn.
Panama.....Oct. 10, '13	C. J. Embree	W. F. Kleene, Ancon, C. Z.
Philadelphia.....Feb. 18, '03	Nathan Hayward	H. Mouradian, Bell Telephone Co. of Penna., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	F. E. Wynne	G. M. Baker, G. E. Co., Oliver Building, Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	F. F. Brand	E. H. Branson, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	J. C. Martin	E. D. Searing, 1185 Kerby Street, Portland, Oregon.
Rochester.....Oct. 9, '14	Frank C. Taylor	J. W. Morrison, Rochester Telephone Co., Rochester, N. Y.
St. Louis.....Jan. 14, '03	A.McR.Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	W. L. Upson	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	Charles A. Lund	Foster Russell, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio.
Toronto.....Sept. 30, '03	William G.Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb.
Urbana.....Nov. 25, '02	L. V. James	A. R. Knight, Univ of Illinois, Urbana,Ill,
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co. Vancouver, B. C
Washington, D. C......Apr. 9, '03	Paul G. Agnew	J. Ernest Smith, McKinley Manual Training School, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	W. L. Teague	J. C. Douthit, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	E. A. Moore, Jr.	A. A. Hofgren, 7542 South Chicago Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio
Clarkson Col. of Tech....Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	P. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Robert Newman	William N. Gittings, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College.....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St.Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	L. N. Miller	M. H. Russell, Kansas State Agri. Col., Manhattan, Kansas.
Kansas Univ. of.....Mar. 18, '08	R. W. Davis	Clark Davis, University of Kansas, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron,State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Harry C. Hartung	William Lash Lipps, 633 Parsons, Easton, Pa.
Lehigh University.....Oct. 15, '02	R. H. Lindsay	R. D. Bean, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech......Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	W. R. Harvey	T. W. Connant, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of.....May 16, '16	George W. Miller	Ray McKibben, University of Minnesota, Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col......May 21, '07	Roy C. Hagen	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr. and Mech. Arts..Feb. 11, '10	John R. Hauser	Landon C. Flournoy, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of. Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of..Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University ,N. D.
Norwich University.....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University...Dec. 20, '02	E. S. Gunn	T. D. Robb, 124 West 10th Ave., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col......Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	A. W. Watter	C. H. Whitwell, University of Oklahoma, Norman, Okla.
Oregon Agr. Col......Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly.	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst...Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terra Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker,Throop Dormitory,Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of.....Dec. 13, '07	S. Stites	E. Tollefson, State Coll. of Wash., Pullman, Wash.
Washington Univ.....Feb. 5, '04	Charles A. Lieber	R. W. Mac Donald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	L. P. Kongsted	L. M. Lubcke, University of Washington, Seattle, Wash.
West Virginia Univ.....Nov. 13, '14	O. P. Jolliffe	D. F Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	B. Luther	N. L. Towle, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School' New Haven, Conn.

Total 59

Digitized by Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI OCTOBER, 1917 Number 10

INSTITUTE MEETING, PHILADELPHIA, OCTOBER 8, 1917

The 333rd meeting of the American Institute of Electrical Engineers will be held in Philadelphia, Pa., October 8, 1917, under the auspices of the Philadelphia Section.

The Institute headquarters during the meeting will be at the Clover Room of the Bellevue-Stratford Hotel, Broad and Walnut Streets, and the registration office at the Clover Room will be open at 1:00 p. m. Members and guests are requested to register promptly on their arrival at the hotel.

The general subject of the meeting will be Industrial Research and three papers will be presented by Dr. F. B. Jewett, Mr. C. E. Skinner, and Dr. A. E. Kennelly. There will be an afternoon and evening session with an informal dinner between the sessions. The regular monthly meeting of the Board of Directors will be held at 11 o'clock a. m., and several committee meetings, will also be held during the day. The program is as follows:

Afternoon Session
Clover Room

1:00 P. M.

Registration office opens

2:00 P. M.

1. *Industrial Research*, by F. B. Jewett.
2. *Industrial Research and its Relation to University and Governmental Research*, by C. E. Skinner.

6:00 P. M.

Stratford Room
Informal Dinner, $2.00 per cover.

Evening Session

8:00 P. M.

3. *Industrial Research and the Colleges*, by A. E. Kennelly.

THE ENGINEERING COUNCIL

The formation of an Engineering Council is the outgrowth of a real need for proper consideration of questions of general interest to engineers and to the public, and to provide the means for united action upon questions of common concern. Many such questions have come up in the past and will arise in greater number in the future. This war has brought out very impressively the actual need for united action of some kind. At present the Council is concerned only with four societies because that seemed the most practical way of getting a group of men together to answer the immediate needs, but these societies do not assume to speak for all engineering societies in the country. Criticism that they are exclusive in any way is utterly mistaken. There is the hope that such a Council by proving itself effectively may lead to much wider cooperation in a strictly representative body for all engineers, and thus pave the way for a very much larger union in the future.

How can the Council be enlarged? By a union of all societies either as the

Digitized by Google

outgrowth of the present Council or by a congress of engineers leading to united action by all societies. The first method will be the most natural one because many local societies and national societies also have a large membership in the four societies at present concerned. We have three classes of engineers to reach: first, those who are members of local societies and not members of national societies; second, those who are members of national societies and not members of local societies; and third, those who are members of no society. The last named class constitutes a very large number in our profession. We are almost as mixed as American citizenship and we suffer therefrom just as much as America with a population representing every race and every people in Europe. There can be no question of the enormous advantage of union. That union should be completed by strengthening the existing agencies and not by the formation of new societies. The national societies are thoroughly national notwithstanding an occasional complaint that they are run by New York. If they have not been able to express the democratic spirit of our country as fully as might be desired it is the fault of the members in all the states and not of the city in which the principal offices are located.

The four societies concerned at present are the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers. They have come together in pairs from time to time in the past for special purposes and there have been general conferences on subjects requiring immediate settlement, but until the Council was definitely organized in June there was no permanent body to advise all the societies. We have had many fruitful discussions in the past leading to useful action. The Standardization Committee which has been organized to represent five societies has passed upon commercial standards of all kinds. This Committee has great possibilities and it should be enlarged enough so that its influence may become very widespread.

Many problems have already been presented before the Council. Its personnel made up of twenty-four men representing equally the four societies is well balanced and judicial. The first duty was necessarily the organization and appointment of standing committees which have already been reported in the press. They might with advantage be mentioned here:

1. Committee on Public Affairs, comprising of Messrs. C. W. Baker, G. F. Swain, S. J. Jennings, and E. W. Rice.

2. Committee on Rules, comprising of Messrs. J. P. Channing, Clemens Hershel, N. A. Carle, and D. S. Jacobus.

3. Committee on Finance, comprising of Messrs. B. B. Thayer, I. E. Moultrop. Calvert Townley, and Alex. C. Humphreys.

Certain questions relate, however, to the war and the assistance that engineers can render. A committee to be called the American Engineering Service Committee was appointed with instructions to invite the cooperation of all engineering societies. This committee in the first instance consists of A. D. Flinn of the Civil Engineers, A. S. McAllister of the Electrical Engineers, George J. Foran of the Mechanical Engineers, G. C. Stone of the Mining Engineers and E. B. Sturgis of the Mining and Metallurgical Engineers. Its present duty is the tabulation and listing of the members of the five societies represented, in order that we as a profession may be in a position to take a larger part in the industries after peace is declared. This tabulation has already in part been done, but in a rather unsystematic and unequal way. It is hoped that the new committee by having additions from other societies may make a final and lasting tabulation of all the engineers in the United States. The list is to be kept in the Engineering

Digitized by Google

Building for general use in Government problems and in the industries. At present the committee is devoting its attention to the immediate need of the hour, namely, the procurement of men for special service in the Government. A list of specialists in the societies has already been completed. There are three methods by which engineers may enter United States Service; first, through some organization, second, through individual application to a department of the Government, and third, through selection by the Conscription Law. But this is War Service wholly and not Civil Service which is the same now as it has always been. As a matter of fact a great many engineers have already entered through the engineering societies, through colleges and through various special boards in Washington. The importance, however, of a complete list of engineers and their professional specialties cannot be over-rated. Such a complete list can be made only with the help of the local as well as of the national societies. The committee mentioned above is organized with George J. Foran as Chairman and A. S. McAllister as Secretary. All societies should respond to the request for cooperation.

Another committee of which Harold W. Buck is Chairman is called the War Committee of Technical Societies. The members are Messrs. H. W. Buck, A. M. Greene, R. N. Inglis, C. R. Corning, G. C. Stone, D. W. Brunton, J. M. Boyle, J. V. Davies, Joseph Bijur, A. S. McAllister, W. D. Richardson and Charles Baskerville. It was appointed to assist any organization in Washington, such as, for instance, the Council of National Defense, the National Research Council and the Naval Consulting Board, in any way in which it can bring to the attention of the engineers of the country the necessity for thought and help in the numerous problems that arise.

A Council organized by the enlargment of the present Engineering Council can be very effective in many ways, without interferring with the autonomy of any individual society. Every society has some definite purpose of its own and also some which it holds in common with all other societies. One of the latter purposes relates to public service and to cooperation. To the end that all societies may understand fully their opportunity, the committee of which Mr. Foran is Chairman has made a complete list of all the societies and their officers and communications will be sent out inviting cooperation and it is hoped that the Council may be successful in arousing sufficient interest to bring about a larger and better Council for all engineers.

In organizing the Council provision was made for the election to membership of other national engineering and technical societies. There is no doubt that rules can be made under which these societies may become members. This will involve consultation and discussion in the future.

The office of the Council will be in the Engineering Building, 29 West 39th St., New York City.

(Signed)

IRA N. HOLLIS, Chairman,
Worcester Polytechnic Institute,
Worcester, Mass.

CALVERT TOWNLEY, Secretary,
115 Broadway, New York City.

Members of the Engineering Council

United Engineering Society:
Clemens Herschel,
B. B. Thayer,
I. E. Moultrop,
Calvert Townley, *Secretary*.

American Society of Civil Engineers:
John F. Stevens,
George F. Swain, *Vice-Chairman*,
Fred H. Newell,
Alex. C. Humphreys,
John D. Galloway.

American Institute of Mining Engineers:
P. N. Moore,
S. J. Jennings,
B. B. Lawrence,
J. Parke Channing,
Edwin Ludlow.

Digitized by Google

American Society of Mechanical Engineers:

Dr. Ira N. Hollis, *Chairman*,
John H. Barr,
Charles Whiting Baker,
Arthur M. Greene, Jr.,
Dr. D. S. Jacobus.

American Institute of Electrical Engineers:

H. W. Buck, *Vice-Chairman*,
E. W. Rice,
N. A. Carle,
P. Junkersfeld,
C. E. Skinner.

EXAMINATION FOR ASSISTANT CIVIL ENGINEER, UNITED STATES NAVY

An examination will be held at the Navy Department, Washington, D. C. to fill vacancies (not less than ten) during the present calendar year in the grade of assistant civil engineer, Corps of Civil Engineers, United States Navy.

The examination to determine the candidate's professional fitness will comprise—a preliminary to determine candidate's general fitness, based on his collegiate record, testimonials, etc., and a final written and oral examination open only to those who have passed the preliminary and a physical examination. No candidate over 26 years of age on July 1, 1917 will be eligible for examination. All papers and other information required of candidates must reach the Bureau of Yards and Docks, Navy Department, Examining Board, Washington D. C., by noon of October 31, 1917. Appointees enter the Corps as assistant civil engineers and are commissioned with the rank of lieutenant (junior grade), Base pay $2,000 per annum, increased 10 per cent every five years up to maximum of $2,800 yearly. Allowance for quarters, $432 yearly. For circular giving complete information apply to Navy Department, Bureau of Yards and Docks, Washington, D. C.

NEW COOPERATIVE COURSES AT M. I. T.

The latest cooperative enterprise established by the Massachusetts Institute of Technology has been undertaken jointly by M. I. T. and the General Electric Company. This is a proposition which on the side of the students gives to them the advantages that an enormous industrial plant with its methods and problems will afford and at the same time the General Electric Company will reap the benefit of the services of a group of selected young men with broad educational foundation.

This course affords a distinctive training for technical and executive responsibilities with manufacturing corporations, particularly electrical ones and covers a period of three years of cooperative engineering and administrative training. While working in Lynn the cooperative students will receive compensation as regular employees and on the successful completion of the course will find themselves instantly placed.

This course is highly regarded by various industrial leaders and the significance of starting an important educational move like this in war times will be appreciated by all who understand the tremendous need which the war is creating for engineers trained in the executive work of production.

PAST SECTION MEETINGS

Denver.—August 16, 1917, Denver Chamber of Commerce. As guest of the engineering group of Denver Chamber of Commerce, the Denver Section attended as a unit a meeting called for the discussion of Military Engineering Problems. Attendance 20.

Fort Wayne.—September 13, 1917, Commercial Club. Address by Mr. Alfred Zimmerman on "Production and Use of the X-Ray". Many interesting demonstrations were made and several photographs were on display. Attendance 70.

Digitized by Google

Minnesota Section.—June 13th, 1917, Elks Club. Election of officers as follows—chairman, F. W. Springer; secretary, A. B. King; member of Board of Directors, E. J. LeBlond; representative to the Joint Engineering Board, R. J. S. Carter. Attendance 20.

San Francisco.—Engineers Club. Election of officers as follows—chairman L. R. Jorgensen; secretary, Allen G. Jones; chairman of Papers Committee, F. C. Piatt; chairman of Entertainment Committee, W. W. Brigg.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its regular monthly meeting, held on September 17, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

McBERTY, FRANK ROBERT, Electrical Engineer, 34 Norfolk St., Strand, W. C. 2, London, England.

To Grade of Member

COOK, JAMES A., Assistant Chief of Laboratory, New York Edison Co., New York, N. Y.

FRANKLIN, RAYMOND E., Superintendent of Electrical Dept., Yukon Gold Co., Dawson, Y. T.

HEIDENREICH, ALLAN H., Electrical Engineer, Firestone Tire & Rubber Co., Akron, O.

SNYDER, FREDERICK T., President, Electric Furnace Corp., Chicago, Ill.

TASSIE, ROBERT WILSON, Electrical Engineer, Havana Electric Railway, Light & Power Co., Havana, Cuba.

THOMPSON, JOHN WEST, District Manager, Central Mexico Light & Power Co., San Luis Potesi, Mexico.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before October 31, 1917.

Andreae, F. V., Anniston, Ala.
Benkesser, G. E., Niagara Falls, N. Y.
Bibighaus, A. J., S. Bethlehem, Pa.
Blitman, C. H., Glasgow, Mont.
Carr, H. D., Rancagua, Chile.
Clarke, J. L., Montreal, Quebec.
Driggs, L. J., Indiana, Pa.
Elsom, C. H., Charleston, W. Va.
Enger, T. K., Pittsfield, Mass.
Gielow, E. L., Phoenix, Ariz.
Kellar, H. A., Glenwood Springs, Colo.
Miller, A. O., New York, N. Y.
Miller, W. H., Ft. Wayne, Ind.
Oakes, C. E., Washington, D. C.
Perlesz, H., Bayonne, N. J.
Prentice, J., Glasgow, Scotland.
Pritchard, A. D., Chicago, Ill.
Sampson, C. V., (Member), La Paz, Bolivia.
Spengler, W. D., (Member), Akron, O.
Stewart, T., Waverley, Mass.
Syron, T. A., Wilkes-Barre, Pa.
Watson, J. L., Schenectady, N. Y.
Weir, C., Okere Falls, N. Z.
Wolfinger, L. F., Los Angeles, Cal.
Total 24.

PERSONAL

PROFESSOR W. S. FRANKLIN, formerly of Lehigh University, has accepted a position as Special Teacher and Lecturer at Massachusetts Institute of Technology, partly in the Department of Physics and partly in the Department of Electrical Engineering. Correspondents will please note Professor Franklin's new address.

D. W. BLAKESLEE, Electrical Engineer and Assistant Superintendent, Penn. Electrical and Mfg. Co., has been ordered to report at Washington for active duty as First Lieutenant in the Engineer Section, Officers' Reserve Corps.

Digitized by Google

HERBERT B. REYNOLDS, formerly with the Interborough Rapid Transit Company of N. Y. as assistant engineer in the motive power department, is now with the United Railways and Electric Company of Baltimore as mechanical assistant to the superintendent of motive power.

D. R. SHEARER, formerly of Knoxville, Tenn., and later engineer for the Boone Fork Lumber Co., has opened an office in the Burrows Bldg., Johnson City, Tenn., for the practise of engineering. Steam, hydroelectric and automatic power plants.

JOHN B. PRICE, has changed his address to 515 Mercantile Library Bldg., Cincinnati, Ohio, where he has opened an office for the Mechanical Appliance Company of Milwaukee.

CAPT. WILLIAM T. TAYLOR, has been gazetted a permanent Captain in the British army. For the past nine months he has been attached to the Royal Flying Corps as an Equipment Officer. In the early part of 1915 he resigned his position in Bolivia, South America to join the British forces. Since 1916 he has been engaged on the French front. Capt. Taylor's permanent address is Vernon Villa, Tetherdown, Muswell Hill, N. London.

OBITUARY

FRANCES B. H. PAINE, a member of the firm of Paine, McClellan and Campion, electrical and consulting engineers, died at his home, 131 Riverside Drive, New York, Sept. 13, 1917, in his forty-ninth year. Mr. Paine, a Fellow in the A. I. E. E., gained his electrical and engineering education with the Westinghouse Company and later was the engineer who was instrumental in installing the power plant of the Ontario Electric Light and Power Company at Niagara Falls. This was one of the first power plants erected there.

In 1891 he was the delegate of the A. I. E. E. to the engineering convention held in connection with the exposition at Frankfort on the Main.

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From August 1, to September 1, 1917)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made. These are taken either from the preface or the text of the book.

All the books listed may be consulted in the United Engineering Society Library.

A TEXT-BOOK ON ROOFS AND BRIDGES. Part II Graphic Statics. By Mansfield Merriman and Henry S. Jacoby. 4th ed., rev. and enl. N. Y. John Wiley & Sons, Inc., Lond., Chapman & Hall, Ltd., 1917. 10+294 pp., 162 illus., 6 pl., 9x6 in., cloth, $2.50.

In addition to a revision and rewriting of the third edition, three new chapters, on Influence Lines for Stresses, Deflection Influence Lines, and Reference Literature of Graphics have been added. The book contains sixty-two more pages than the third edition, and twenty-four additional drawings.

ELECTRICAL MEASUREMENTS. By Frank A. Laws. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 13+719 pp., 442 illus., 8x6 in., cloth, $5.

A general treatment of the subject, based on the author's experience at the Massachusetts Institute of Technology, which emphasizes matters of importance to the student of electrical engineering. Intended as a general reference work as well as a text for students. References to more detailed discussions of the various methods are appended to each chapter.

ENGINEERING FOR MASONRY DAMS. By William Pitcher Creager. N. Y., John Wiley & Sons, Inc., Lond., Chapman & Hall, Ltd., 1917. 11+237 pp., 88 illus., 10 diagrams, 9x6 in., cloth, $2.50.

Contents Investigations and Surveys: The Choice of Type of Dam; Forces Acting on Dams;

Digitized by Google

Requirements for Stability of Gravity Dams; General Equations for Design of Gravity Dams; The Design of Solid Non-Overflow Gravity Dams; The Design of Solid Spillway Gravity Dams; The Design of Hollow Dams; The Design of Arch Dams; Preparation and Protection of the Foundation; Flood Flows; Details and Accessories.

HANDBOOK OF CLEARING AND GRUBBING.

Methods and Cost. By Halbert Powers Gillette. N. Y., Clark Book Co., Inc., 1917. 240 pp., 67 illus., 7x5 in., cloth, $2.50.

A general review of all the methods, compiled from state and federal bulletins, periodicals and personal experience. Gives costs in detail whenever possible.

ORGANISATION PHYSIOLOGIQUE DU TRAVAIL.

Par Jules Amar. Préface de Henry Le Chatelier. Paris, H. Dunod et E. Pinat, 1917. 12+374 pp., 134 illus., 10x7 in., pap., 18 franc.

Written the author states "to assist the organization of labor according to national laws, the assignment to each of his true function in the social machine, the collaboration of the sound and the mutilated man in the work of tomorrow, to formulate in a few words the doctrine of the maximum utilization of the physical and psychical forces, without neglecting the moral factor." Describes the methods used in physiological laboratories to measure work and discusses the practical applications of the results in such systems as the Taylor system. One-third of the work discusses the re-education of the mutilated.

RAILROAD CONSTRUCTION.

Theory and Practice. A Text-Book for the Use of Students in Colleges and Technical Schools, and a Hand-Book for the Use of Engineers in Field and Office. By Walter Loring Webb. 6th. ed. rev. and enl.; N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 15+831 pp., 218 illus., 7x4 in., cloth, $4.

The revision of the fifth edition has been so extensive that it has almost amounted to a rewriting of the book, comparatively few pages have not been changed. The work of the committees of the American Railway Engineering Association has been followed throughout, and considerable new matter on railroad surveys and the handling of surveying parties has been added.

SHAPE BOOK.

Containing Profiles, Tables, and Data Appertaining to the Shapes, Plates, Bard, Rails, and Track Accessories Manufactured by the Carnegie Steel Company. Pittsburgh, (copyright 1917). 352 pp., 270 illus., 8x5 in., leather, $1.

STANDARD TABLE OF ELECTROCHEMICAL EQUIVALENTS.

And their Derivatives with Explanatory Text on Electrochemical Calculations, Solutions of Typical Practical Examples and Introductory Notes on Electrochemistry. By Carl Hering and Frederick H. Getman. N. Y., D. Van Nostrand Co., 1917. 10+130 pp., 8 illus., 7x4 in., leather, $2.

Intended to provide a table of constants, based on the latest and best fundamental values, for calculating the amounts of substances electrolytically deposited, dissolved or otherwise chemically changed by an electric current.

THE APPLICATION OF EFFICIENCY PRINCIPLES.

By George H. Shepard. N. Y., The Engineering Magazine Co., 1917. 10+368 pp., 7 diagrams, 9x6 in., cloth, $3.

Takes Harrington Emerson's statement of these principles and attempts to show how each can be practically applied. Illustrations from various fields of industry, are given to show the operation of each principle. One endeavor has been made to strike a mean between a theoretical consideration of efficiency and a description of its application to one specific industry.

THE ELEMENTS OF HYDROLOGY.

By Adolph F. Meyer. N. Y., John Wiley & Sons, Inc., Lond., Chapman & Hall, Ltd., 1917. 12+487 pp., 287 illus., 2 diagrams, 3 maps, 9x6 in., cloth, $4.

Intended to provide engineers with a clear statement of the most important physical bases and applications of the fundamental principles underlying the science, rather than as a text or reference book. Contents: Introduction; The Atmosphere: Its Temperature, Pressure and Circulation; Water: Its Various States and Their Properties; Precipitation: Its Occurrence and Distribution; Evaporation from Water Surfaces; Evaporation from Land Areas; Transpiration; Deep Seepage; Runoff; Stream-Flow Data; Supplementing Stream-Flow Data; Modification of Stream Flow by Storage; Notes to Teachers of Hydrology; Index.

THE IRON ORES OF LAKE SUPERIOR.

Containing Some Facts of Interest Relating to Mining and Shipping of the Ore and Location of Principal Mines. 3d ed. with original maps of the ranges.

Digitized by Google

By Crowell & Murray. Cleveland, The Penton Press Co., 1917. 316 pp., 7 illus., 13 maps, 9x6 in., cloth, (gift of the authors.)

Contents: Early History of the Lake Superior Region; Geology; Mineralogy; Production of Ore; Dock Equipment; Classification of Lake Superior Iron Ores; Valuation of Lake Superior Iron Ores; Beneficiation of Ores; Methods of Analysis; Geology of the Wakefield Area of the Eastern Gogebic; Progress of Development of the Cuyuna Range; Description of Mines and Ores with Maps; Index to Mines and Ores.

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-273. Wanted: Master Mechanic, technically educated, experienced in maintenance of mine machinery, electrically driven, air compressors, centrifugal pumps, etc. Location Peru-elevation 15,000 feet. Two year contract. State salary desired and experience.

V-274. Young men with technical training in the Operating Department of large power company. In answering give full information as to age, education, experience, etc.

V-275. Position open in the sales department of large and progressive manufacturer of electrical power apparatus for graduate electrical engineer with about two years' practical experience. Previous sales experience not necessary or desirable. Unusual opportunity for right man.

V-276. Special Service at the Front. Wanted: Chemical and Gas Engineers. Resourceful men, experienced in developing chemical and gas apparatus and materials.

V-278. Production Manager, with technical education and practical experience, for work involving assembling of auto radiators in factory employing about 500 men. Salary about $3,000. Location, vicinity of Buffalo. Please give details of experience.

V-279. A large manufacturing firm in Milwaukee wants a young man for development, experimental and research work on an electrical apparatus used in the gas, steel mill, and coke oven industries. Applicant should be about 23 to 28 years of age, should have the equivalent of a university technical training, and should have two or three years' practical experience if possible. Furnish references with reply.

V-280. Wanted: Young technically educated engineer, married, with practical turbine and boiler experience, familiar with a-c. and d-c. substation operation, including battery operation and maintenance, who is willing to make himself useful on other central station detail when necessary. Location, West Indies; climate healthful; excellent opportunity.

MEN AVAILABLE

822. Graduate Electrical Engineer, with experience as Examiner in U. S. Patent Office, and knowledge of general and patent law, desires location in patent department of manufacturing firm in New York City; has thorough knowledge of patent office procedure and ability in writing specifications and prosecuting applications.

823. Graduate Electrical Engineer, Mem. A. I. E. E., age 35, married; fourteen years' experience in power plant transmission and distribution system, and industrial plant design, construction and operation; ability for research and efficiency work. Four years as chief draftsman with large

Digitized by Google

hydroelectric organization, and three years with engineering department of large mining and smelter concern. Desires position with industrial plant, public utility organization or consulting engineering firm.

824. Mechanical and Electrical Engineer, of fifteen years' successful practical experience. Can design, supervise or organize, original or new work where initiative, tact and perseverance are required. Temperamentally qualified to adapt self to various personnel within or without an organization. At present employed, but desires new position where there is ample opportunity to produce results.

825. Technical Graduate, now employed, with nine years' practical experience designing, purchasing and installing electrical equipment, covering practically the entire electrical field, open for position offering exceptional opportunities for advancement. None other considered. Married. Salary $200 to start. Available at once.

826. Electrical Engineer, with thorough scientific knowledge and eight years' engineering experience, desires position where originality, thoroughness and energy are required. Technical graduate, including post-graduate studies. Possesses good practical knowledge of chemistry. Can handle men. American; aged 31; single; at present employed.

827. Power Plant Electrical Engineer, desires to make change. Technical graduate; age 35. Ten years' experience in laying out plans for power plants, transmission lines and railway overhead. At present engaged as engineer and executive head of street railway and power company. Has had experience in construction work.

828. Electrical Engineer, married, at present employed, seeks position in Western Canada, either to supervise construction work or take charge of a power plant. Has had wide experience in all branches of electric power.

829. Electrical Engineer, age 40, desires position with public utility company as superintendent of electric meter department and electrical laboratory. Very broad experience in modern meter and instrument testing and installation, high and low tension. Present position assistant superintendent of electrical laboratory in city of 200,000. Salary desired $1500.

830. General Manager. Graduate engineer; in complete charge of entire business, office, finance, sales and production. Four years production manager and general manager of big automobile and truck factory. Ten years' experience in large plants in the East, on production end. Wide experience in costs and organization. Available on short notice.

831. Electrical Engineer, technical graduate, 27 years old, unmarried, five years' electrical, business, and manufacturing experience. State nature of work, conditions, and salary.

832. Electrical Engineer, age 26, 1915 graduate; desires position with central station company or manufacturing company in design work. At present employed in manufacturing field.

833. Electrical Engineer, married, twenty-nine years old. Two years in General Electric testing dept. Two years with large consulting engineering corporation. Now employed as electrical engineer by company in bituminous district in Pennsylvania. Wish to get out of mining work. Prefer to locate in the East.

834. Technical Graduate, with six and a half years' experience in operation and maintenance of electric car lighting equipment of large Eastern railroad company; also A. H. I. business course, desires position where ability and initiative will bring responsible promotion. Age 31, married.

835. Electrical Engineer, expert in solving practical electrical problems, would change to position offering such work as major feature. Three years with manufacturing company and five years with operating company—design, testing and erection experience. University graduate; technically trained; married. Mem. A. I. E. E. and S. P. E. E.

836. Engineer-Manager, with ten years' experience with utilities, desires connection where intelligence, energy, capacity and business sense, added to a technical knowledge, will be of use. Experience includes operation, erection, superintendence and management, commercial and executive work with modern electrical power systems. Position of responsibility—superintending or managing and building up power and lighting property preferred. Available on short notice.

837. Electrical Engineer, technical graduate, with executive ability, age 30; three years' experience in design and manufacture of electrical machinery, specializing in induction motors; five years' experience in generating, d-c. and a-c. substation operation, and high and low-tension distribution of central

Digitized by Google

station company. Available on short notice. Minimum salary $2500.

838. Electrical Engineer, with ten years' general engineering experience and fifteen years in construction, operation and maintenance of hydroelectric plants. At present superintendent of large hydroelectric station in the East; will consider change if good business inducements are given. Minimum salary considered East or South, $4000; middle West or Pacific Coast, $5000.

839. Electrical Engineer, university graduate (1910), 31 years old, has had seven years' experience in Europe and the U. S. in designing and developing small power plants, generators motors and transformers, automatic telephones, signalling and measuring instruments; also, special testing training.

840. University Electrical Graduate. Fifteen years engineer in electrical lines, chiefly telephone. Experienced in construction, maintenance, design, testing, cost accounting and valuation. Three years in building construction. Now on machinery design and in charge of manufacture. Wishes to re-engage in electrical work, preferably of an experimental, inventive or investigative nature.

841. Recent electrical engineering graduate, desires position in an electrical laboratory where a variety of original research and experimental work is conducted. At present employed on test work for a large electrical manufacturing company. Age 22. Vicinity of Philadelphia or New York preferred.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1917-1918.

PRESIDENT.

(Term expires July 31, 1918)

E. W. RICE, Jr.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1918)
JOHN J. CARTY

(Term expires July 31, 1919)
H. W. BUCK

VICE-PRESIDENTS.

(Term expires July 31, 1918)

B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON
FREDERICK BEDELL
A. S. McALLISTER
JOHN H. FINNEY

MANAGERS.

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS
E. H. MARTINDALE

(Term expires July 31, 1921)
WALTER A. HALL
WILLIAM A. DEL MAR
WILFRED SYKES

TREASURER (Term expires July 31, 1918)
GEORGE A. HAMILTON

SECRETARY.
F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

LIBRARIAN
HARRISON W. CRAVER

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1917.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1892-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK 1916-17.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to October 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

E. W. Rice, Jr., Chairman,
General Electric Company, Schenectady, N. Y.
H. W. Buck, Harold Pender,
N. A. Carle, L. T. Robinson,
George A. Hamilton, C. E. Skinner.

FINANCE COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
Walter A. Hall, Charles Robbins.

MEETINGS AND PAPERS COMMITTEE

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary,
Westinghouse E. and M. Company, Pittsburgh, Pa.
B. A. Behrend, Harris J. Ryan,
W. I. Slichter,
and the chairmen of the technical committees

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
M. G. Lloyd, L. T. Robinson,
Henry H. Norris, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
80 Park Place, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller, H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 West 23rd St., New York.
William McClellan, F. L. Rhodes,
Henry H. Norris, W. I. Slichter.

SECTIONS COMMITTEE.

Walter A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
P. H. Daggett, Vice-Chairman
John B. Fisken, H. W. Flashman,
A. M. Schoen,
and the chairman of all Institute Sections, *ex-officio.*

COMMITTEE ON STUDENT BRANCHES.

(Sub-Committee of Sections Committee.)
P. H. Daggett, Chairman,
University of North Carolina, Chapel Hill, N. C.
Alexander M. Gray, A. C. Lanier,
C. Francis Harding, Charles F. Scott.

MEMBERSHIP COMMITTEE.

H. A. Pratt, Chairman,
W. E. and M. Company, 165 Broadway, N. Y.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
W. E. and M. Company,
165 Broadway, New York.
H. W. Buck, P. Junkersfeld,
N. A. Carle, John W. Lieb,
John J. Carty, E. W. Rice, Jr.,
C. E. Skinner.

HEADQUARTERS COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
A. S. McAllister, F. L. Hutchinson.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, W. S. Gorsuch,
Frederick Bedell, F. C. Hanker,
Joseph Bijur, H. M. Hobart,
L. F. Blume, P. Junkersfeld,
James Burke, A. E. Kennelly,
G. A. Burnham, G. L. Knight,
N. A. Carle, F. A. Laws,
P. H. Chase, A. S. McAllister,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
William A. Del Mar, C. E. Skinner,
A. M. Dudley, N. W. Storer,
E. J. Edwards, John B. Taylor,
H. W. Fisher, R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau St., New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, A. S. McAllister,
B. A. Behrend, M. I. Pupin,
James Burke, E. B. Rosa,
John J. Carty, David B. Rushmore,
Gano Dunn, Charles F. Scott,
H. M. Hobart, Clayton H. Sharp,
John W. Lieb, C. E. Skinner,
Elihu Thomson.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, A. S. McAllister,
Gano Dunn, Schuyler Skaats Wheeler

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.
Term expires July 31, 1919.
Charles F. Brush, Chairman,
481 The Arcade, Cleveland, Ohio.
N. W. Storer, C. C. Chesney.
Term expires July 31, 1920.
Carl Hering, Harris J. Ryan,
Robert Lindsay.
Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.
Term expires July 31, 1922.
C. A. Adams, L. A. Ferguson,
S. W. Stratton.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1918.
L. T. Robinson, Harold Pender,
C. E. Skinner.
Term expires July 31, 1919.
B. A. Behrend, John J. Carty,
A. S. McAllister.

Ex-Officio.

E. W. Rice, Jr., President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to October 1, 1917.

POWER STATIONS.

Philip Torchio, Chairman,
N. Y. Edison Company, 124 E. 15th St., New York.

L. P. Crecelius, H. S. Putnam,
W. S. Gorsuch, F. A. Scheffler,
P. M. Lincoln, R. F. Schuchardt,
S. A. Moss, H. L. Wallau,
I. E. Moultrop, W. F. Wells,
B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Company, Niagara Falls, N. Y.

A. O. Austin, P. M. Lincoln,
J. A. Brundige, L. C. Nicholson,
H. W. Buck, W. D. Peaslee,
Wallace S. Clark, D. W. Roper,
E. E. F. Creighton, Harris J. Ryan,
H. W. Fisher, P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman,
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams, William A. Del Mar,
A. H. Armstrong, J. V. B. Duer,
A. H. Babcock, John Murphy,
Reinier Beeuwkes, Charles F. Scott,
W. H. Blood, Jr., H. M. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Company, Cleveland, O.

H. W. Cope, Charles D. Knight,
James Dixon, A. M. MacCutcheon,
A. M. Dudley, A. G. Pierce,
R. H. Goodwillie, James M. Smith,
A. L. Hadley, H. Weichsel,
C. A. Kelsey, J. B. Wiard,
R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin, R. C. Powell,
C. E. Clewell, E. B. Rosa,
J. R. Cravath, W. D'A. Ryan,
Bassett Jones, Clayton H. Sharp,
T. S. Perkins, W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE

[Not yet appointed.]

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
Commonwealth Edison Company, 72 W. Adams St., Chicago, Ill.

E. E. F. Creighton, P. M. Lincoln,
Leslie N. Crichton, A. A. Meyer,
James C. Dow, N. L. Pollard,
L. L. Elden, F. E. Ricketts,
E. M. Hewlett, Philip Torchio,
H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

F. A. J. Fitzgerald, Chairman,
Fitzgerald Laboratories, Niagara Falls, N. Y.

Lawrence Addicks, F. A. Lidbury,
Joseph L. Dixon, T. H. Schoepf,
I. R. Edmands, J. A. Seede,
Carl Hering, Willis R. Whitney.

ELECTROPHYSICS.

[Not yet appointed.]

TELEGRAPHY AND TELEPHONY.

L. F. Morehouse, Chairman,
A. T. and T. Company, 195 Broadway, New York.

E. F. W. Alexanderson, William Maver,
R. E. Chetwood, Kempster B. Miller,
E. B. Craft, John Stone Stone,
M. M. Davis, John B. Taylor,
A. H. Griswold, J. L. Wayne.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.

D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr., Guy Hill,
M. W. Day, O. P. Loomis,
L. A. Doggett, G. A. Pierce, Jr.,
G. E. Edgar, H. M. Southgate,
W. L. R. Emmet, E. A. Sperry,
W. R. Furlong, Wilfred Sykes,
H. L. Hibbard, F. W. Wood.

USE OF ELECTRICITY IN MINES.

H. H. Clark, Chairman,
Bureau of Mines, 40th and Butler Sts., Pittsburgh, Pa.

Frank H. Armstrong, R. L. Kingsland,
Graham Bright, A. B. Kiser,
W. A. Chandler, Charles Legrand,
F. J. Duffy, Charles M. Means,
L. C. Ilsley, K. A. Pauly,
H. M. Warren,

ELECTRICAL MACHINERY.

Alexander M. Gray, Chairman,
Cornell University, Ithaca, N. Y.

B. A. Behrend, H. F. T. Erben,
A. M. Dudley R. B. Williamson,
James Burke.

INSTRUMENTS AND MEASUREMENTS.

S. G. Rhodes, Chairman,
104 East 32nd St., New York.

P. G. Agnew, F. V. Magalhaes,
F. P. Cox, T. S. Perkins,
Clayton H. Sharp.

IRON AND STEEL INDUSTRY.

F. D. Egan, Chairman,
Pittsburgh Crucible Steel Co.,
Midland, Pa.

EDUCATIONAL.

E. J. Berg, Chairman,
Union College, Schenectady, N. Y.

Alexander Gray, Chester W. Rice,
Charles S. Howe, C. E. Skinner,
E. B. Merriam, W. J. Slichter.

Digitized by Google

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

C. O. Mailloux, John J. Carty.
Paul M. Lincoln, H. W. Buck.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

W. I. Slichter, Edward D. Adams,
Harold Pender, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

W. S. Franklin, G. W. Pierce.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney Charles W. Stone,
Calvert Townley.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON ENGINEERING COUNCIL.

H. W. Buck, N. A. Carle,
E. W. Rice, Jr., P. Junkersfeld,
C. E. Skinner.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

COMMITTEE ON GENERAL ENGINEERING, ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE.

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.

Robert Julian Scott, Christchurch, New Zealand,

T. P. Strickland, N. S. W. Government Railways Sydney, N. S. W.

W. G. T. Goodman, Adelaide, South Australia.

James S. Fitzmaurice, Perth, West Australia.

L. A. Herdt, McGill Univ., Montreal, Que.

Henry Graftio, Petrograd, Russia.

A. S. Garfield, 45 Boulevard Beausejour Paris 16 E. France.

Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.

John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to October, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	Thomas C. Taliaferro, S. E. Underwriters Ass'n., Atlanta, Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	H. M. Hope	Ira M. Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Wm. J. Crumpton	C.A.Keller,Edison Building, Chicago, Ill.
Cleveland.....Sept. 27, '07	C. M. Rakestraw	C. S. Ripley, 711 Williamson Building, Cleveland, Ohio.
Denver.....May 18, '15	Norman Read	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	H. H. Higbie	H. J. Wyckoff, Detroit Edison Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne,Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Unoin Tel. Co., Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	V. Karapetoff (Acting Secretary), Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	W. F. Barnes	W. F. Barnes, Kansas City, Mo.
Los Angeles.....May 19, '08	Don Morgan	A. W. Nye, University of Southern California, Los Angeles, Cal.
Lynn.....Aug. 22, '11	J. M. Davis	R. D. Thomson, General Electric Company, West Lynn, Mass.
Madison.....Jan. 8, '09	J. R. Price	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	Arthur Simon	Soren H. Mortensen, Allis-Chalmers Mfg. Co., West Allis, Wis.
Minnesota.....Apr. 7, '02	F. W. Springer	A. B. King, Electric Machinery Company, Minneapolis, Minn.
Panama.....Oct. 10, '13	C. J. Embree	W. F. Kleene, Ancon, C. Z.
Philadelphia.....Feb. 18, '03	Nathan Hayward	H. Mouradian, Bell Telephone Co. of Penna., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	F. E. Wynne	G. M. Baker, G. E. Co., Oliver Building, Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	F. F. Brand	E. H. Branson, General Electric Company, Pittsfield, Mass.
Portland, Ore.....May 18, '09	J. C. Martin	E. D. Searing, 1185 Kerby Street, Portland, Oregon.
Rochester.....Oct. 9, '14	Frank C. Taylor	J. W. Morrison, Rochester Telephone Co., Rochester, N. Y.
St. Louis.....Jan. 14, '03	A.McR.Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	W. L. Upson	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	Charles A. Lund	Foster Russell, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, 1257 Fernwood Ave., Toiedo, Ohio.
Toronto.....Sept. 30, '03	William G.Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb.
Urbana.....Nov. 25, '02	L. V. James	A. R. Knight, Univ of Illinois, Urbana,Ill,
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co. Vancouver, B. C
Washington, D. C......Apr. 9, '03	Paul G. Agnew	J. Ernest Smith, McKinley Manual Training School, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M.M.Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	W. L. Teague	J. C. Douthit, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	E. A. Moore, Jr.	A. A. Hofgren, 7542 South Chicago Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of......Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio
Clarkson Col. of Tech....Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

C. O. Mailloux, John J. Carty.
Paul M. Lincoln, H. W. Buck.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

W. I. Slichter, Edward D. Adams,
Harold Pender, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

W. S. Franklin, G. W. Pierce.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney Charles W. Stone,
Calvert Townley.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, F. B. H. Paine,
Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON ENGINEERING COUNCIL.

H. W. Buck, N. A. Carle,
E. W. Rice, Jr., P. Junkersfeld,
C. E. Skinner.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

COMMITTEE ON GENERAL ENGINEERING, ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE.

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.

Robert Julian Scott, Christchurch, New Zealand,

T. P. Strickland, N. S. W. Government Railways Sydney, N. S. W.

W. G. T. Goodman, Adelaide, South Australia.

James S. Fitzmaurice, Perth, West Australia.

L. A. Herdt, McGill Univ., Montreal, Que.

Henry Graftio, Petrograd, Russia.

A. S. Garfield, 45 Boulevard Beausejour Paris 16 E. France.

Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.

John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to October, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	Thomas C. Taliaferro, S. E. Underwriters Ass'n., Atlanta, Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L. M. Potts, Industrial Bldg., Baltimore, Md.
Boston.....Feb. 13, '03	H. M. Hope	Ira M. Cushing, 84 State St., Boston, Mass.
Chicago.....1893	Wm. J. Crumpton	C. A. Keller, Edison Building, Chicago, Ill.
Cleveland.....Sept. 27, '07	C. M. Rakestraw	C. S. Ripley, 711 Williamson Building, Cleveland, Ohio.
Denver.....May 18, '15	Norman Read	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	H. H. Higbie	H. J. Wyckoff, Detroit Edison Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	J. L. Wayne, 3rd	C. A. Cora, care Central Unoin Tel. Co., Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	V. Karapetoff (Acting Secretary), Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	W. F. Barnes	W. F. Barnes, Kansas City, Mo.
Los Angeles.....May 19, '08	Don Morgan	A. W. Nye, University of Southern California, Los Angeles, Cal.
Lynn.....Aug. 22, '11	J. M. Davis	R. D. Thomson, General Electric Company, West Lynn, Mass.
Madison.....Jan. 8, '09	J. R. Price	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	Arthur Simon	Soren H. Mortensen, Allis-Chalmers Mfg. Co., West Allis, Wis.
Minnesota.....Apr. 7, '02	F. W. Springer	A. B. King, Electric Machinery Company, Minneapolis, Minn.
Panama.....Oct. 10, '13	C. J. Embree	W. F. Kleene, Ancon, C. Z.
Philadelphia.....Feb. 18, '03	Nathan Hayward	H. Mouradian, Bell Telephone Co. of Penna., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	F. E. Wynne	G. M. Baker, G. E. Co., Oliver Building, Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	F. F. Brand	E. H. Branson, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	J. C. Martin	E. D. Searing, 1185 Kerby Street, Portland, Oregon.
Rochester.....Oct. 9, '14	Frank C. Taylor	J. W. Morrison, Rochester Telephone Co., Rochester, N. Y.
St. Louis.....Jan. 14, '03	A. McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	J. E. Woodbridge	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	W. L. Upson	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	Charles A. Lund	Foster Russell, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio.
Toronto.....Sept. 30, '03	William G. Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb.
Urbana.....Nov. 25, '02	L. V. James	A. R. Knight, Univ of Illinois, Urbana, Ill,
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co. Vancouver, B. C
Washington, D. C......Apr. 9, '03	Paul G. Agnew	J. Ernest Smith, McKinley Manual Training School, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	M. M. Bridgewater	L. E. Tighe, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	L. I. Davis, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	W. L. Teague	J. C. Douthit, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	E. A. Moore, Jr.	A. A. Hofgren, 7542 South Chicago Avenue, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	Bradley B. Brown	H. F. Fielder, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	E. G. Peterson	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio
Clarkson Col. of Tech....Dec. 10, '15	H. H. Plank	Philip R. Cloke, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	H. W. McKinley	F. G. Stiers, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Robert Newman	William N. Gittings, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College.....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St.Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	L. N. Miller	M. H. Russell, Kansas State Agri. Col., Manhattan, Kansas.
Kansas Univ. of.....Mar. 18, '08	R. W. Davis	Clark Davis, University of Kansas, Lawrence, Kansas.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron,State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Harry C. Hartung	William Lash Lipps, 633 Parsons, Easton, Pa.
Lehigh University.....Oct. 15, '02	R. H. Lindsay	R. D. Bean, Lehigh University, South Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech.....Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	W. R. Harvey	T. W. Connant, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of.....May 16, '16	George W. Miller	Ray McKibben, University of Minnesota, Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Roy C. Hagen	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	F. C. Holtz, University of Nebraska, Lincoln, Nebraska.
North Carolina Col. of Agr. and Mech. Arts..Feb. 11, '10	John R. Hauser	Landon C. Flournoy, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of..Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University ,N. D.
Norwich University.....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ.....Feb. 9, '12	R. H. Bennett	W. W. Wickerham, 125 S. Gilbert Street, Ada, Ohio.
Ohio State University...Dec. 20, '02	E. S. Gunn	T. D. Robb, 124 West 10th Ave., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	A. W. Watter	C. H. Whitwell, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	J. B. Kelly.	
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terra Haute, Ind.
Rhode Island State Col..Mar. 14, '13	A. W. Thayer	Carl A. Burdick, Rhode Island State College, Kingston, R. I.
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker,Throop Dormitory,Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	John D. Hindle	E. S. Smithson, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of.....Dec. 13, '07	S. Stites	E. Tollefson, State Coll. of Wash., Pullman, Wash.
Washington Univ.....Feb. 5, '04	Charles A. Lieber	R. W. Mac Donald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	L. P. Kongsted	L. M. Lubcke, University of Washington, Seattle, Wash.
West Virginia Univ.....Nov. 13, '14	O. P. Joliffe	D. F Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	B. Luther	N. L. Towle, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	A. W. Cahoon	J. P. Allen, Sheffield Scientific School' New Haven, Conn.

Total 59

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI NOVEMBER, 1917 Number 11

INSTITUTE MEETING IN NEW YORK, NOVEMBER 9, 1917

The 334th meeting of the American Institute of Electrical Engineers will be held in the Auditorium of the Engineering Societies Building, 33 West 39th Street, New York, at 8:15 p.m.

The paper of the evening is entitled "*An Experimental Method of Obtaining the Solution of Electrostatic Problems with Notes on High-Voltage Bushing Design*," by Mr. Chester W. Rice, of the General Electric Co. The paper is published in this issue of the PROCEEDINGS and reprints will be distributed at the meeting.

A thorough discussion of the paper is desired, and non-members of the Institute who are interested in this subject are cordially invited to attend and take part in the meeting.

THE ENGINEERING FOUNDATION AND THE NATIONAL RESEARCH COUNCIL

In order to give an outline of the relations existing between the National Research Council and the Engineering Foundation, as well as a brief review of the work accomplished, there is appended the Report of the Foundation for the year ending Sept. 20, 1917 together with the reciprocal resolutions adopted, and the letter of Major Millikan, Vice-Chairman of the National Research Council, epitomizing some of the accomplishments of the Council made possible by the financial support during the past year extended by the Engineering Foundation.

REPORT OF SECRETARY TO THE ENGINEERING FOUNDATION FOR THE YEAR SEPTEMBER 1916-1917.

September 20, 1917

To the
Engineering Foundation Board

Gentlemen:

As this meeting terminates the year's agreement under which the Engineering Foundation has appropriated its income to the National Research Council, a brief summary of what has been accomplished seems called for.

The Research Council was organized on the 19 September 1916. The Executive Committee was appointed at that meeting; since that date two other meetings of the Council have been held, one in Boston on 13-14 November, and the other in Washington on 19 April. During the intervals between the meetings of the Research Council, the Exectuive Committee has conducted all of the business of the Council. There have been twenty-nine meetings of the Executive Committee, thirteen in New York up to the first of May, fifteen in Washington subsequently, and one in Boston.

The meetings in New York were devoted to the organization of the Research Council and especially to the appointment of Committees. At the outset, the Council had no very clear idea of the way in which it was to organize; there were several other groups of scientific men at work, among them, the Research Committee of the American Association for the Advancement of Science and the Engineering Com-

Digitized by Google

mittee of the Advisory Commission to the Council of National Defense. Time was spent in straightening out these two principal complications, both of which were satisfactorily adjusted. The upshot of these negotiations is to leave the Research Council as the only representative, national body of research men, assisting the Government.

During the period up to May, the Executive Committee in New York selected carefully the personnel of some twenty-five principal committees, and of a larger number of sub-committees; so carefully were these chosen that of the entire number, several hundred, there have been only one or two declinations.

Some of the important steps in the development of the Research Council are the establishment of the Military Section, composed of the Members of the Council connected with the Government and resident in Washington. This Section put the Research Council into close contact with the most important officials of the Army and Navy. From it has grown the Washington Office of the Council, and the recognition of the Research Council as the "Department of Science and Research of the Council of National Defense;" and the establishment of the Washington Office after the Council of National Defense has officially recognized the Research Council. About this time Dr. Hale Chairman of the Council, appointed Dr. Millikan to be Vice-Chairman to represent the Council in Washington, and Dr. Millikan has since then been in charge of the work of the Council.

At the request of the Secretary, Dr. Millikan has prepared a brief report of some of the work of the Research Council during its first year, which is appended to this report. It shows that the Research Council has been active in much of the important work under way in our preparations for war, and that it has rendered effective services to the Government.

During the early stages much discussion took place regarding the formation of an Engineering Committee of the Research Council,—how it should best be formed and what scope it should have. In April, this was worked out by the Chairman, Mr. Dunn, most satisfactorily with the cooperation of the four principal Engineering Societies. This committee has since been one of the most active of the Research Council, under the efficient handling of Dr. Durand, who came on from California to act as head of the office in Washington and under whom work of the Engineering Committee has been conducted. The work of the Secretary for the last few months has been principally with Dr. Durand and this Committee.

The funds of the Engineering Foundation have been spent in general administrative work, that is to say, in the payment of traveling expenses, expenses of committees, stationery, printing, salaries, etc., of this office, principally. Money has not been spent directly in the solution of scientific problems.

There is appended a brief financial statement, showing the operation of the Foundation for the year resulting in a surplus of $4,775, which added to the surplus of $11,670 on 16 September 1916, makes a surplus at this date $16,445. Against this the only liability is $1000; and the Foundation has in this office furniture and fittings costing $838.

The Engineering Foundation at its meeting in January approved a budget for the year amounting to $12,510 for the Research Council; subsequently it authorized $400 more for furniture, in all $12,910. The total amount disbursed on account of the Research Council to the 20 September 1917, is $10,445,—that is $2465 less than the amount appropriated.

The Foundation, in July 1916, made an appropriation of $1000 to Messrs. Marx and Durand of California for researches on wear of gears. The Secretary has recently written to

Digitized by Google

Prof. Marx asking whether it would be possible, by the payment of expenses already incurred, to release the Foundation from subsequent expenses in this matter. An answer was requested by 20 September, but none has yet been received. The Foundation may be released from the obligation; but, for the present, it should be assumed that this $1000 is tied up, leaving available for other purposes of the Foundation a surplus of $15,445.

The Engineering Foundation has been an important factor in the formation of the National Research Council and in the guidance of its early life. It is, I think, safe to say, had it not been for the assistance given by the Foundation to the Research Council, that when its opportunity came to be of service to the country it would not have been ready to act, and would not have been authorized as the "Department of Science and Research of the Council of National Defense."

The Research Council no longer requires the financial assistance of the Foundation, which is therefore free to devote its resources to other work.

Faithfully, yours,

CARY T. HUTCHINSON,
Secretary.

FINANCIAL STATEMENT OF ENGINEERING FOUNDATION FOR THE YEAR 29 SEPTEMBER 1916-1917

EXPENDITURES

Account	Amount
Salary of Secretary	$5,000
Traveling Expenses	930
Current Office Expenses (ex Stationery)	2,133
Office Furniture and Fittings	838
Stationery (N. Y. and Washington)	1,034
Committee Appropriations	510
TOTAL EXPENDITURES	$10,445

INCOME FOR THE YEAR

From Securities (including bank interest)	10,220	
Mr. Swasey's Gift	5,000	
TOTAL INCOME		15,220
SURPLUS for the Year		
" on 16 September 1916.		4,775
" on 20 September 1917.		11,670
		16,445

BUDGET

Authorized for the Research Council	12,510	
Authorized additional (for furniture)	400	
Total Budget	12,910	
Expenditures (above)	10,445	
Remainder, not used		2,465

THE ADAM'S FUND

Gift of Mr. Adams	5,000	
Disbursements to 20 September 1917	1,597	
BALANCE, 20 September 1917		3,403

CARY T. HUTCHINSON,
Secretary.

20 September 1917.

RECIPROCAL RESOLUTIONS EXCHANGED BETWEEN THE ENGINEERING FOUNDATION AND NATIONAL RESEARCH COUNCIL.

From the National Research Council to The Engineering Foundation.

"As the year for which the cooperative arrangement was made between the Engineering Foundation and the National Research Council will soon expire, the Research Council wishes again to record its high appreciation of the liberal financial and personal assistance which the Foundation and its members have afforded in the organization and support of the work of the Council in this first year of existence. It seems exceedingly desirable to maintain close relations between engineers and research workers which the Research Council for the first time succeeded in establishing. Accordingly, the Council wishes to express the hope that it may be practicable to continue some effective form of cooperation between the two bodies and it would be glad to appoint representa-

Digitized by Google

tives to consider this matter with men designated by the Foundation."

From The Engineering Foundation to the National Research Council.

"RESOLVED, That The Engineering Foundation receives with pleasure the resolution of the National Research Council expressing appreciation of the financial and personal assistance rendered to the organization and work of the Council during the past year. Reciprocating the Council's desire for the maintenance of close relations between workers in science and in engineering, the Foundation hereby declares that it will be its policy to continue the cooperation between the two bodies in all practicable ways that may be now, or may become, mutually available, such ways consisting of the interchange of helpful suggestions, advice, information, office representation and similar facilities, and in addition a recognition of community of purpose that shall promote in the field of engineering research increasingly intimate relations between engineering and science.

The reciprocal designation of the Secretary of each of the bodies as an assistant Secretary of the other for the purpose of enabling both bodies to have offices in both New York and Washington is favorably regarded, and the Foundation welcomes and gladly accepts the offered assistance of the Research Council in the national co-relation of the engineering research work of the Foundation to which the Foundation's resources will be devoted."

DR. MILLIKAN'S LETTER

Edited for publication.

September 7, 1917.

DR. CARY T. HUTCHINSON, Secretary,
The Engineering Foundation,
33 West 39th Street, New York.

Dear Dr. Hutchinson:

The following is a statement of some of the work of the National Research Council, condensed with difficulty on account of the great variety and scope of the Council's activities.

All of the work of the Research Council that touches upon Army or Navy problems is carried on with the advice, co-operation or control, as the case may be, of the representatives of the various Departments of the Army or Navy under which such work comes.

The Council has co-operated in the establishment and organization of the submarine experimental work at Nahant and has also established a very active submarine station at New London, another at San Pedro, California, and has been instrumental in the organization of groups working at New York, Chicago, and Madison, Wisconsin.

There has resulted a great practical advance in the art of submarine detction which it is not desirable to go into further.

The Physics Committee of the Council has distributed to various groups twenty or more large problems in physics, which are being actively worked upon and some of which have already been solved. Among the latter are the location of aircraft by sound, the development of fire control for anti-aircraft guns, telephoning between airplanes, protection of balloons from ignition by static charges and the development of new and improved methods of measuring muzzle velocities.

The Chief Officer of the Signal Corps of the Army has asked the Research Council to act as the Division of Science and Research of the Signal Corps, and in this capacity the Council has organized a Sound Ranging Service in the Signal Corps, a new Meteorelogical Service in the Signal Corps, and is now drawing specifications for scientific instruments to be used on airplanes. It has sent a dozen of the best physicists in the country to France to aid the American Expeditionary Forces with their scientific knowledge and is selecting a personnel of several hundred men who are to be engaged in the scientific services of the Army and Navy.

The Chemistry Committee has perfected an elaborate organization for the handling of all of the chemical problems which arise in the Army and in the Navy, and it has distributed some 150 chemical problems which are being attacked in the chemical laboratories of the country.

The Psychology Committee has presented to the Secretary of War and the Adjutant General a vast program for the selection of officers for the Army from officers' reserve camps and for the classification of drafted men. In fact it has called in most of the best known psychologists of the country and has

Digitized by Google

organized them and employment experts into a large group in whose hands the War Department has placed the largest responsibilities regarding the examination and selection of men.

The Medical Committee has enlisted the services of a large number of medical men of the country both in medical research problems and in the regular work of the Sanitary Corps of the Army.

The Engineering Committee has contributed in no small degree to the development of devices for the protection of ships from submarines. It has organized a large group which are now working on the development of steel protective devices for use of the soldiers at the front, and through cooperation with the National Advisory Committee for Aeronautics it has carried on extensive and important researches in the development of airplanes and airplane engines.

Turning to the work of the special committees of the Council, the Nitrate Committee has made an elaborate study and report which has been made the basis for the expenditure by the government of large sums of money upon the erection of a nitrate plant.

The Gas Warfare Committee has had for six months 120 chemists working on the problems of gas warfare and the results already attained have been of the utmost importance,—so important that the Army and Navy have placed large appropriations at the disposal of this Committee for its researches.

The Optical Glass Committee, by taking from the research laboratories like the Geophysical Laboratory and the Bureau of Standards, a dozen more silicate chemists and putting them directly in the works of the Bausch and Lomb Company and the Pittsburgh Plate Glass Company, has in six months' time developed in America the production of optical glass from nothing up to 20,000 pounds a month and in two months more this figure will have been multiplied two or three fold.

The Psychiatry Committee has established abroad a Laboratory for the study of shell shock.

The Foreign Service Committee, which the Council sent abroad at once upon the outbreak of the war, was wholly responsible for the sending back to this country of a French, English and Italian Scientific Mission, which brought with them the contributions which science had made to the war, both in the matter of instruments and methods, and unquestionably saved months of time in putting the United States abreast of the European situation, as regards modern scientific methods in warfare. It is difficult to overestimate the stimulus to American participation in the war which resulted directly from the action of the Research Council in sending abroad at once this Foreign Service Committee composed of seven of the best scientists in the country.

These are a few of the results which have followed from the assistance which the Engineering Foundation gave in the bringing into being of the National Research Council. It is hoped that they are only a small part of the results which will have been attained by the end of the second year of its existence.

Sincerely yours,

(Sgd.) R. A. MILLIKAN,
Vice-Chairman.

A. I. E. E. MEETING IN PHILADELPHIA, OCTOBER 8, 1917

The 333d meeting of the Institute was held in Philadelphia in the Clover Room of the Bellevue-Stratford Hotel, in two sessions. The afternoon session with an attendance of 176 was called to order 2:20 p. m. by Vice-President B. A. Behrend who after a few brief remarks turned the meeting over to Chairman L. T. Robinson. Dr. A. E. Kennelly read his paper, "Industrial Research and the Colleges." There was a lively discussion following the reading of the paper by Professor Karapetoff, Professor Gray, Dr. Sharp, Professor Slichter, and Professor Pender. Major F. B. Jewett being unable

Digitized by Google

to personally attend the meeting, Captain E. B. Craft, of his staff, read his paper on "Industrial Research."

This paper was discussed by Professor Karapetoff, Mr. L. F. Morehouse of the American Telephone & Telegraph Company, Professor Gray, and several others, Dr. A. E. Kennelly and Captain Craft closed the discussion. The meeting adjourned at 4:45 p. m.

An informal dinner was served at 6:00 p. m. in the Stratford Room of the Bellevue-Stratford Hotel. There were 204 men present at the dinner, including several army and navy representatives from Camp Dix and the Philadelphia Navy Yard respectively. Mr. W. L. R. Emmet, member of the Naval Consulting Board addressed the members and guests following the dinner upon the subject of the engineers' work in the present war, and the best means of presenting new suggestions to the authorities as at present constituted.

The evening session with L. T. Robinson presiding was called at 8:20 p. m. with 277 members and guests present. Mr. C. E. Skinner read his paper on "Industrial Research and Its Relation to University and Governmental Research." The discussion was opened by Senior Vice President, B. A. Behrend and was followed in rapid succession by Professor Karapetoff, Professor Gray, Professor Pender, Professor C. A. Adams, Professor C. F. Scott, Mr. Agnew, and others, the discussion being lively throughout. Mr. C. E. Skinner closed the discussion. Before the meeting adjourned, Professor C. F. Scott made a formal motion that the Board of Directors of the Institute be requested to consider the advisability of the formation of a Committee on Research Work. This motion was put to a vote and was carried without any dissenting votes. Mr. L. T. Robinson who presided, and who kept the meeting in high good humor by his impromptu remarks and contributions to the discussion, then adjourned the meeting, following a formal voicing by local Chairman N. Haywood of the deep appreciation of the Philadelphia Section to the speakers and to all the visiting members who had taken the time to attend the Philadelphia meeting, and made it a successful and enjoyable affair.

In addition to the technical sessions, the Board of Directors and the following committees also held meetings at the Bellevue-Stratford Hotel: Standards Committee, Meetings and Papers Committee, Finance Committee, Electrical Machinery Committee, Power Stations Committee.

The Board of Directors held its meeting at 11:00 a.m. and adjourned at 1:00 p.m. The members were the guests of Dr. Harold Pender at luncheon. The Board held an adjourned meeting at 5:00 p.m., after the close of the technical session.

The Meetings and Papers Committee held an adjourned meeting on Tuesday morning at 10:00 a.m.

A. I. E. E. DIRECTORS' MEETING, PHILADELPHIA, OCTOBER 8, 1917

The regular monthly meeting of the Board of Directors was held at the Bellevue-Stratford Hotel, Philadelphia, on Monday, October 8, 1917, at 11:00 a.m.

There were present: Vice-Presidents B. A. Behrend, Boston, L. T. Robinson, Schenectady, A. S. McAllister, New York; Managers John B. Taylor, Schenectady, Harold Pender, Philadelphia, C. E. Skinner, East Pittsburgh, N. A. Carle, Newark, N. J., C. S. Ruffner, St. Louis, Walter A. Hall, West Lynn, Wm. A. Del Mar, New York, Wilfred Sykes, East Pittsburgh; Treasurer George A. Hamilton, Elizabeth, N. J., Secretary, F. L. Hutchinson, New York.

In the absence of President Rice Senior Vice-President Behrend presided.

The action of the Finance Committee in approving monthly bills amounting to $7,771.75, was ratified.

Digitized by Google

The report of the Finance Committee submitting the annual budget covering the estimated expenditures of the Institute during the appropriation year beginning October 1, 1917, amounting to $118,000.00, was approved and the budget was adopted.

The reports of the Board of Examiners of its meetings held September 17 and October 1, were presented, and the actions taken at these meetings were approved. Upon the recommendation of the Board of Examiners the following action was taken upon pending applications: 39 Students were ordered enrolled, 59 applicants were elected to the grade of Associate, 4 applicants were elected to the grade of Member, 10 applicants were transferred to the grade of Member, and 2 applicants were transferred to the grade of Fellow.

The Meetings and Papers Committee recommended that the remaining regular monthly meetings for the present administrative year be held in New York, with the exception of one meeting to be held in Cleveland at a date to be decided later. Recommendation approved.

Upon recommendation of the committee it was voted that such regular monthly meetings as may be held outside New York City hereafter be held on the regular meeting day, namely, the second Friday of the month.

A considerable amount of other business was transacted by the Board, reference to which will be found under appropriate headings in this and future issues of the PROCEEDINGS.

THE WORK OF THE MEETINGS AND PAPERS COMMITTEE

It is the privilege of the editor of the A. I. E. E. to attend and take part in the monthly meetings of the Meetings and Papers Committee, and it is believed that a review of the proceedings at these meetings will be of interest to the membership. The Committee held two sessions in Philadelphia last month, one on Monday morning, October 8, at which the question of meetings was considered, and its principal session on Tuesday, which was called to order at 9:30 in the morning and continued without intermission until 2:00 p.m.

The October and November meetings each year are the most important meetings of this Committee because the general outline of the activities for the coming year has to be decided early in the season in order that the work of arranging suitable programs for the coming meetings may be taken in hand promptly, and the necessary papers secured. This is an important fact for members of the Institute to keep in mind. Excellent suggestions in regard to meetings and papers have been made from time to time by the membership which the Committee has found unavailable because its plans for the season were to far advanced to admit of alteration.

The committee invites and welcomes suggestions from the membership as to ways and means of improving our meetings and publications, and the earlier such suggestions are received the more valuable they will be to the committee in formulating the season's program.

MEETINGS FOR 1917-18

The location of the meetings for the coming season was discussed at considerable length at the October meeting of the Committee, and some diversity of opinion existed as to whether it was advisable for the Institute to continue the practise, inaugurated last year, of holding part of the regular monthly meetings outside of New York and part at the New York headquarters. Those advocating holding all of the regular monthly meetings in New York based their contention upon the fact that it involved a rather heavy burden upon the Board of Directors and various committee members to travel long distances to the meetings each month at

Digitized by Google

different cities, whereas New York is the most readily accessible place in the country and a trip to New York for the Institute meetings can generally be combined with other business affairs. It was also thought by some that the large proportion of the membership exclusively engaged in military or civil work in connection with the war would make it difficult to organize meetings and secure satisfactory attendance outside of New York.

On the other hand it was pointed out that the meetings outside of headquarters during the past season had been well attended and had attained greater enthusiasm and success than those held in New York. It was also suggested that the Institute being a national society, should by holding some of the regular meetings outside of New York give an opportunity for many members at local points to come into more direct contact with the Officers and Directors of the Institute and in this way further the work of the local sections. While no formal decision was reached on this matter it was tentatively arranged to hold five meetings in New York and one meeting, exclusive of the Philadelphia meeting and the Annual Convention, in another city.

A suggestion was made, which was received very favorably, that instead of holding meetings under the auspices of one Section, several adjacent Sections might cooperate in organizing an Institute meeting to be held at a central point under the auspices of all the cooperating Sections. As there are many more Sections than there are regular monthly Institute meetings each year, this plan would give a maximum number of Sections an opportunity to participate actively in regular Institute meetings.

Papers for 1917-18

The Committee had before it for consideration 17 manuscripts and 10 proposed papers. Three of the manuscripts which were approved by the technical committees to which they had been submitted were accepted; three were rejected for various causes, and eleven were held in abeyance pending further investigation by the technical committees or revisions at the hands of the authors. In general, an offer to write a paper upon any subject can not be definitely acted upon by the committee, and proposals to write papers are almost always answered by an invitation to submit the manuscripts, which will be judged upon their merits.

The consideration and examination of manuscripts occupies a large share of the Committee's time and no one attending these meetings can fail to be impressed with the absolute fairness and impartiality with which every manuscript is considered. Generally speaking, every acceptable paper finds a place on the program sometime during the season, and the present policy of the committee is to print in the Proceedings, without presentation at a meeting, such acceptable papers as do not fit in well with the programs of the regular meetings or those which are likely to be only of interest to a small proportion of the membership.

The selection of Institute papers is a problem presenting many perplexities and grows increasingly difficult as the field of electrical engineering broadens. It is manifestly impossible, from a financial standpoint, to cover any special branch of electrical engineering thoroughly, but every effort is made to keep pace with all important advances in all branches of the industry. The Committee is, of course, limited in a large degree in its selection of papers to such manuscripts as are submitted to it, although it frequently solicits papers upon subjects that it considers will be of general interest. The 16 technical committees cover practically every branch of electrical engineering and upon these committees rests the responsibility of procuring papers relating to their respective fields. A preponderance of papers on one subject or a lack of papers on another subject reflects, in general, either the activity

Digitized by Google

or lack of activity of the technical committees to which those subjects pertain. The Meetings and Papers Committee earnestly desires to publish such papers as will be most useful and valuable to the membership, but in order to do so, such papers must be forthcoming from the membership.

One of the most frequent criticisms made by the members of the committee is that many papers are too long and their value is reduced, to a degree, by the inclusion of an unnecessary amount of data and verbiage. A number of papers otherwise acceptable has been returned by the committee to the authors with the suggestion to condense them, sometimes as much as 50 per cent. Another class of papers which meets with considerable criticism is those mathematical papers which do not state in plain language either the problem involved, or the conclusions reached. Mathematical solutions are highly desirable in their proper place, but the committee believes that a plain statement of the subject, treatment, and conclusions deduced should be made the principal feature of every paper. Often the mathematical solution could preferably be included in an appendix.

In conclusion, the Meetings and Papers Committee undoubtedly desires to publish such material as will be of the greatest interest and value to the membership, and in order to keep in touch with the requirements and wishes of the members it would welcome constructive criticism and suggestions from them. In the final analysis, the value of the Institute publications depends upon the interest and activity of all the membership. The volume of our publications was materially reduced last season due to the cancellation of several meetings and the unsettled conditions following the declaration of war, but it is planned to hold the usual number of meetings this season so that our publications will no doubt resume their usual proportions.

ILLUMINATING ENGINEERING SOCIETY MEETING

The next meeting of the New York Section of the Illuminating Engineering Society will be held in the Engineering Building, 33 West 39th St., Thursday, Nov. 8, 1917 at 8 p.m.

Two papers will be presented at this meeting of great interest to members of the A. I. E. E.: first, "*Illuminating Engineering as a Commercial Force*," by a committee of the Lighting Sales Bureau of the N. E. L. A.; second, "*Value of Illuminating Engineering to the Gas Industry*," by Robert Pierce.

ELECTRICAL ENGINEERS NOMINATED FOR COMMISSIONS IN NAVY

Under date of September 20, 1917, Rear-Admiral S. C. Palmer, Chief of Bureau of Navigation, U. S. Navy, addressed a letter to the President of the Institute, stating that the Secretary of the Navy had authorized the commissioning of one hundred graduate electrical engineers as Lieutenants, Junior Grade, in the Reserve Force of the Navy; that three organizations, namely, the Naval Consulting Board, the National Research Council, and the A. I. E. E., were each requested to nominate eighty-five men possessing certain specified qualifications; and that from the total of two hundred fifty-five nominations thus received a Navy Board would select the one hundred men to be commissioned.

A conference of representatives of the three organizations mentioned above was held shortly after the receipt of Admiral Palmer's letter, and in accordance with a decision made at this conference, a circular containing all necessary information was prepared and mailed to the entire membership of the Institute in the United States, in order that each member who desired to do so might have an opportunity to apply and that other members might

Digitized by Google

have an opportunity to recommend desirable candidates.

At the meeting of the Board of Directors of the Institute that was held in Philadelphia October 8, a committee of five members of the Board was appointed to consider and act upon the applications and nominations received by the Secretary.

This committee, consisting of Messrs. H. W. Buck, chairman, A. S. McAllister, L. T. Robinson, Wilfred Sykes, and John B. Taylor, met at Institute headquarters October 16 and 17, considered the applications received, and transmitted eighty-five nominations on behalf of the Institute to Admiral Palmer under date of October 18. The Naval Consulting Board and the National Research Council also transmitted their nominations upon the same date. At a conference of representatives of the three organizations concerned held October 18, it was decided that candidates or others desiring further information regarding their applications should be referred to the Navy Department at Washington.

It is hoped that at a later date it will be possible to print in the PROCEEDINGS the entire list of the men who are finally commissioned.

A considerable number of applications was received, or was completed, after the committee had completed its report on the evening of Wednesday, October 17, and consequently were not considered by the committee. These applications will be held at Institute headquarters for consideration in connection with other opportunities for service that may be brought to the Institute's attention by the authorities of the Army, Navy, or other department of the Government.

GOVERNMENT SERVICE

Electrical Engineers: The Signal Corps of the Army is in need of the services of electrical engineers, more particularly of those who have had radio-communication experience of some kind. The work is expected to consist of experimental trials of radio apparatus, in general laboratory work, and in the instruction of personnel in the use of new types of radio equipment.

Those who believe that their training or experience fit them for service of this character are requested to communicate with the Secretary of the Institute, 33 West 39th St., New York, stating fully their education, experience and their exact present status in the draft.

Electricians: Training schools for temporary specialists of the Coast Artillery Corps will be opened about Nov. 19, 1917. Men who have had an electrical education equivalent to two years college work or who are thoroughly familiar with electricity and electrical apparatus and are now proficient in mathematics should apply for this course. They will be fitted for Electrician Sergeants, 2d Class, who are charged with the care, operation and repair of electrical installations at Coast Artillery posts, which include power plants, telephone systems, searchlights, gasoline engines, cable repairs, etc. The monthly rate of pay is $44.00 for first enlistment, with promotion as vacancies occur to Electrician Sergeant, 1st Class at $51.00 per month; Engineer $71.00 per month, and Master Electrician at $81.00 per month. All rates of pay are in addition to clothing, quarters, subsistence, and medical attendance.

Applications should be sent as follows:

Persons residing in New England States to Commanding Officer, North Atlantic Coast Artillery District, Boston, Mass.; those in Middle Atlantic States to Commanding Officer, Middle Atlantic Coast Artillery District, Fort Totten, New York; those in Southern States to Commanding Officer, South Atlantic Coast Artillery District, Charleston, South Carolina.

Mechanical Draftsman: The Ordnance Department needs mechanical draftsman and, unless the situation is corrected, war preparations will be

Digitized by Google

seriously retarded. An intelligent investigation will be made of the fitness of every volunteer and such volunteer given an immediate rating according to ability.

At the request of the Ordnance Department, the National Civil Service Reform League, at 79 Wall St., New York City, is answering inquiries and will furnish application forms on request.

THE ENGINEERING COUNCIL

The Engineering Council met on October 11th in the rooms of the American Society of Mechanical Engineers, Engineering Societies Building, New York.

The Rules Committee submitted a draft of rules for the admission of other societies to the Council and progress was made in their consideration.

The Committee on Public Affairs reported on a number of requests that the Council support pending or proposed legislation.

Remedial laws intended to promote hydroelectric development were favored and Council voted to offer its cooperation to the United States Chamber of Commerce which is interesting itself in this matter.

A movement to coordinate, unify and strengthen the work of various engineering committees cooperating with the federal authorities at Washington was favorably considered. Messrs. H. W. Buck and Charles Whiting Baker were appointed Council conferees.

FUTURE SECTION MEETINGS.

Baltimore.—November 9th, 1917. Subject: Military Aeronautics.

Chicago.—November 25, 1917. Subject: Engineering Data for the Determination of an Electric Rate Problem. Speaker: Bert H. Peck.

Cleveland.—November 19, 1917. Subject: Lighting, Its Use in Warfare.

Pittsburgh.—November 13, 1917. Subject: Electric Arc Welding. Speaker: A. M. Candy.

December 8, 1917. Annual Banquet.

PAST SECTION MEETINGS.

Milwaukee.—October 3, 1917, Lecture Hall, Public Museum. Illustrated lecture by Mr. C. L. Lucas on "Making of High-Explosive Howitzer Shells." Attendance 1000.

Panama.—September 9, 1917, Cristobal, C. Z. Address by Lieut. E. L. Vanderkloot, U. S. N., on "Submarines." Attendance 27.

September 30, 1917, Pedro Miguel. Paper: "Automatic Railway Signals" by E. C. McDonald. Attendance 24.

Pittsburgh.—September 11, 1917, Union Arcade. Subject: What the Institute Does for the Engineer. Speakers: Messrs. Dudley, Welch, Chubb, Hanker and Kirker. Attendance 72.

October 9, 1917, Union Arcade. Papers: (1) "Effect of Drum Shape on Motor Rotary of Shaft Hoists" by F. L. Stone; (2) "Storage Battery Mine Locomotives" by J. G. Carroll. Attendance 120.

San Francisco.—September 28, 1917, Engineers Club. Papers: (1) "Civilian Engineer and the War" by John D. Galloway; (2) "Engineering Problems of the War" by Frank Rieber. Attendance 105.

Schenectady.—October 5, 1917, Edison Club Hall. Address by Dr. Charles Alexander Richmond on "The Higher Law of Efficiency." Attendance 220.

Toledo.—September 26, 1917, Builders Exchange. Illustrated lecture by Mr. John Gilmartin on "Electrical Characteristics in Circuits Supplying Arc Furnaces." Attendance 32.

Toronto.—September 21, 1917. Engineer's Club. Moving pictures showing hydroelectric developments in Canada. The Chairman, Mr. Wills Maclachlan, made a short address covering some interesting figures relating to the uses of Water Power in Canada. Attendance 60.

Digitized by Google

have an opportunity to recommend desirable candidates.

At the meeting of the Board of Directors of the Institute that was held in Philadelphia October 8, a committee of five members of the Board was appointed to consider and act upon the applications and nominations received by the Secretary.

This committee, consisting of Messrs. H. W. Buck, chairman, A. S. McAllister, L. T. Robinson, Wilfred Sykes, and John B. Taylor, met at Institute headquarters October 16 and 17, considered the applications received, and transmitted eighty-five nominations on behalf of the Institute to Admiral Palmer under date of October 18. The Naval Consulting Board and the National Research Council also transmitted their nominations upon the same date. At a conference of representatives of the three organizations concerned held October 18, it was decided that candidates or others desiring further information regarding their applications should be referred to the Navy Department at Washington.

It is hoped that at a later date it will be possible to print in the PROCEEDINGS the entire list of the men who are finally commissioned.

A considerable number of applications was received, or was completed, after the committee had completed its report on the evening of Wednesday, October 17, and consequently were not considered by the committee. These applications will be held at Institute headquarters for consideration in connection with other opportunities for service that may be brought to the Institute's attention by the authorities of the Army, Navy, or other department of the Government.

GOVERNMENT SERVICE

Electrical Engineers: The Signal Corps of the Army is in need of the services of electrical engineers, more particularly of those who have had radio-communication experience of some kind. The work is expected to consist of experimental trials of radio apparatus, in general laboratory work, and in the instruction of personnel in the use of new types of radio equipment.

Those who believe that their training or experience fit them for service of this character are requested to communicate with the Secretary of the Institute, 33 West 39th St., New York, stating fully their education, experience and their exact present status in the draft.

Electricians: Training schools for temporary specialists of the Coast Artillery Corps will be opened about Nov. 19, 1917. Men who have had an electrical education equivalent to two years college work or who are thoroughly familiar with electricity and electrical apparatus and are now proficient in mathematics should apply for this course. They will be fitted for Electrician Sergeants, 2d Class, who are charged with the care, operation and repair of electrical installations at Coast Artillery posts, which include power plants, telephone systems, searchlights, gasoline engines, cable repairs, etc. The monthly rate of pay is $44.00 for first enlistment, with promotion as vacancies occur to Electrician Sergeant, 1st Class at $51.00 per month; Engineer $71.00 per month, and Master Electrician at $81.00 per month. All rates of pay are in addition to clothing, quarters, subsistence, and medical attendance.

Applications should be sent as follows:

Persons residing in New England States to Commanding Officer, North Atlantic Coast Artillery District, Boston, Mass.; those in Middle Atlantic States to Commanding Officer, Middle Atlantic Coast Artillery District, Fort Totten, New York; those in Southern States to Commanding Officer, South Atlantic Coast Artillery District, Charleston, South Carolina.

Mechanical Draftsman: The Ordnance Department needs mechanical draftsman and, unless the situation is corrected, war preparations will be

Digitized by Google

seriously retarded. An intelligent investigation will be made of the fitness of every volunteer and such volunteer given an immediate rating according to ability.

At the request of the Ordnance Department, the National Civil Service Reform League, at 79 Wall St., New York City, is answering inquiries and will furnish application forms on request.

THE ENGINEERING COUNCIL

The Engineering Council met on October 11th in the rooms of the American Society of Mechanical Engineers, Engineering Societies Building, New York.

The Rules Committee submitted a draft of rules for the admission of other societies to the Council and progress was made in their consideration.

The Committee on Public Affairs reported on a number of requests that the Council support pending or proposed legislation.

Remedial laws intended to promote hydroelectric development were favored and Council voted to offer its cooperation to the United States Chamber of Commerce which is interesting itself in this matter.

A movement to coordinate, unify and strengthen the work of various engineering committees cooperating with the federal authorities at Washington was favorably considered. Messrs. H. W. Buck and Charles Whiting Baker were appointed Council conferees.

FUTURE SECTION MEETINGS.

Baltimore.—November 9th, 1917. Subject: Military Aeronautics.

Chicago.—November 25, 1917. Subject: Engineering Data for the Determination of an Electric Rate Problem. Speaker: Bert H. Peck.

Cleveland.—November 19, 1917. Subject: Lighting, Its Use in Warfare.

Pittsburgh.—November 13, 1917. Subject: Electric Arc Welding. Speaker: A. M. Candy.

December 8, 1917. Annual Banquet.

PAST SECTION MEETINGS.

Milwaukee.—October 3, 1917, Lecture Hall, Public Museum. Illustrated lecture by Mr. C. L. Lucas on "Making of High-Explosive Howitzer Shells." Attendance 1000.

Panama.—September 9, 1917, Cristobal, C. Z. Address by Lieut. E. L. Vanderkloot, U. S. N., on "Submarines." Attendance 27.

September 30, 1917, Pedro Miguel. Paper: "Automatic Railway Signals" by E. C. McDonald. Attendance 24.

Pittsburgh.—September 11, 1917, Union Arcade. Subject: What the Institute Does for the Engineer. Speakers: Messrs. Dudley, Welch, Chubb, Hanker and Kirker. Attendance 72.

October 9, 1917, Union Arcade. Papers: (1) "Effect of Drum Shape on Motor Rotary of Shaft Hoists" by F. L. Stone; (2) "Storage Battery Mine Locomotives" by J. G. Carroll. Attendance 120.

San Francisco.—September 28, 1917, Engineers Club. Papers: (1) "Civilian Engineer and the War" by John D. Galloway; (2) "Engineering Problems of the War" by Frank Rieber. Attendance 105.

Schenectady.—October 5, 1917, Edison Club Hall. Address by Dr. Charles Alexander Richmond on "The Higher Law of Efficiency." Attendance 220.

Toledo.—September 26, 1917, Builders Exchange. Illustrated lecture by Mr. John Gilmartin on "Electrical Characteristics in Circuits Supplying Arc Furnaces." Attendance 32.

Toronto.—September 21, 1917. Engineer's Club. Moving pictures showing hydroelectric developments in Canada. The Chairman, Mr. Wills Maclachlan, made a short address covering some interesting figures relating to the uses of Water Power in Canada. Attendance 60.

Digitized by Google

PAST BRANCH MEETINGS.

University of Arkansas.—October 15, 1917. Officers were elected as follows: President, E. P. O'Neal; vice-president, H. H. Robinson; secretary-treasurer, J. C. Douthit. Attendance 12.

Armour Institute.—October 10, 1917, Lecture Room. Election of Mr. Ralph A. Newlander as chairman, to take the place of Mr. E. A. Moore who did not return to Armour. Address by Prof. E. E. Freeman on "The Advantages of Students becoming Affiliated with a Student Branch of the A. I. E. E." Attendance 16.

University of California.—September 19, 1917. Election of officers as follows: A. J. Swank, chairman; W. C. Pomeroy, vice-chairman; G. F. Teale, secretary; M. L. Frandy, treasurer.

Clarkson College of Technology.—October 3, 1917. Election of officers as follows: R. H. Hoyt, chairman; E. S. Parks, secretary; A. F. Allen, treasurer.

October 17, 1917. Address by Professor Paul Cloke on "Summer Work with Mr. Lamme in the Teachers' Summer School at Westinghouse." Attendance 13.

University of Colorado.—September 20, 1917, Engineering Building. Election of Mr. E. A. Thomas as vice-chairman. Address by Prof. H. B. Dwight on "The Purpose, and Advantages to Students of the A. I. E. E." Attendance 40.

October 4, 1917. Engineering Building. Address by Mr. Shepherd on "The Application of Electricity to the Separation of Minerals by the Oil Flotation Process." Attendance 30.

Colorado State Agricultural College.—October 9, 1917, Electrical Building. Electrical Show and demonstration meeting. Attendance 55.

Kansas State Agricultural College.—September 13, 1917, Anderson Hall. Address by Dean A. A. Potter on "Opportunities for the Engineer." Joint meeting with other engineering societies. Attendance 350.

September 20, 1917. Denison Hall. Subject: Summer Experiences. Speakers; Messrs. M. A. Durland, Homer Cross, Morton Stigers, L. G. Alford, and C. R. Witham. Attendance 31.

September 27, 1917. Anderson Hall. Address by Dr. J. D. Walters on "Discoveries and Inventions." Joint meeting with other engineering societies. Attendance 350.

Lafayette College.—October 6, 1917, Pardee Hall. Paper: "The Induction Motor as a Generator" by Wm. L. Lipps. Abstracts from electrical press by Harry C. Hartung on "The Illumination of the Panama-Pacific Exposition." Attendance 18.

October 13, 1917, Pardee Hall. Papers: (1) "The Motor Requirements in the Manufacture of Silk" by W. S. Williams. (2) "The Electrical Equipment of the Reynold-Terrel Silk Co." by H. G. F. Richter. Attendance 16.

Massachusetts Institute of Technology.—October 4, 1917. Addresses on "Advantages of Affiliation with the A. I. E. E." Attendance 128.

University of Michigan.—October 10, 1917. Address by Prof. J. C. Parker on "The Engineer's Work and His Duties to Society." Brief remarks by Mr. Cannon on "The Students' Relation to the Institute." Attendance 25.

University of Nebraska.—October 10, 1917, Electrical Engineering Building. Short talks by Prof. V. L. Hollister and Oskar E. Edison on "The Purpose of the Institute and the Organization of the Local Branch." Illustrated address by Mr. A. A. Kluge on "Wireless Telegraphy with Particular Reference to Its Use in the Present War." Election of officers as follows: Chairman, Olin J. Ferguson; secretary, Oskar E. Edison. Attendance 56.

Ohio Northern University.—September 26, 1917. Temporary officers were elected as follows: Chairman, W. F. Parsons; secretary, A. J. Ferlic; treasurer, A. Alholm; executive committee, J. E. Hawe, R. E. Long, W. E. Ward, L. D. Beatty. Address by Prof. McEachron on "The Object of and Benefits of the A. I. E. E."

Digitized by Google

October 10, 1917. Addresses as follows: (1) "The Submarine" by A. Alholm; (2) "British Workshops and the War" by R. E. Long. Attendance 25.

Ohio State University.—October 5, 1917, Robinson Laboratory. Short talk by Prof. F. C. Caldwell to new men. Addresses on "Summer Experiences" by Messrs. G. E. Park, A. P. Grasser, H. Lockett, and C. E. Winegartner. Attendance 31.

University of Oklahoma.—October 9, 1917. Engineering Building. Addresses as follows: (1) "Electrical Engineering in the War" by L. F. Woods; (2) "Hello Oklahoma" by F. G. Tappan; (3) "Vacation Education" by Ben. F. Shultz; (4) "The National A. I. E. E." by L. W. W. Morrow. Attendance 24.

Syracuse University.—October 4, 1917. Election of officers as follows: Chairman, H. F. Buchanan; secretary, G. J. Lowell; Address by Mr. J. R. Busteed on "The Power Station of the United Electric Light and Power Company of New York City."

October 11, 1917. Mr. C. F. Swartz spoke on "Experiences with the General Electric Company."

Virginia Polytechnic Institute.—October 9, 1917, Science Hall. Election of officers as follows: Chairman, Baxter McIntosh; secretary-treasurer, J. A. Carr; executive committee, Messrs. L. E. Henley, E. S. Smithson, H. H. Frith, C. Lee, L. S. Randolph and S. R. Pritchard.

Yale University.—September 28, 1917 Enrollment of new members.

ASSOCIATES ELECTED OCTOBER 8, 1917

ALLEN, LEWIS C., Sales Engineer, Fairbanks Morse & Co.; res., 1005 19th St., Parkersburg, W. Va.

ANDERSON, CLARENCE AUBREY, Manager, Branch Office, Canadian General Electric Co., Sydney, N. S.

ANTHONY, ROBERT H., New England Representative, R. Thomas & Sons Co., 261 Franklin St., Boston, Mass.

BEALL, JOHN COLLIER, American Telephone & Telegraph Co.; res., 653 Piedmont Ave., Atlanta, Ga.

BINNEY, ERIC A., Electrical Engineer, Wagner Electric Mfg. Co.; res., 5225 Page Blvd., St. Louis, Mo.

BUCK, ANDREW MARSDEN, Power House Operator, Surf Inlet Power Co., Ltd., Surf Inlet, B. C.

CHANDLER, WILFRED WARREN, Engineering Dept., Blackstone Valley Gas & Electric Co., Pawtucket, R. I.; res., Foxboro, Mass.

COLEMAN, J. EMILE, Efficiency Engineer, Mergenthaler Lynotype Co., Brooklyn, N. Y.; res., 15 Rector Pl., Red Bank, N. J.

CONNOR, ROBERT A., Elec. Engineer & Manager, Thordarson Electric Mfg. Co.; res., 3512 West Monroe St., Chicago, Ill.

EATON, RAYMON MANSON, Chief Electrician, Okonite Co.; res., 144 Sherman St., Passaic, N. J.

*FEDER, JOSEPH BROWN, Test Dept., New York Edison Co., 92 Vandam St., New York, N. Y.; res., 35 N. Walnut St., E. Orange, N. J.

FIELDING, CHARLES HOWARD, Chief Electrician, Hess Steel Corp., Station O; res., 2830 E. Madison St., Baltimore, Md.

FISKE, GEORGE ISAAC, Engineer, Choralcelo Co., Boston; res., 11 Wyoming St., Roxbury, Mass.

GARBUTT, HARRY LEE, Manager, Line Material Section, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

GIBSON, FAIRLEY JAMES, Assistant Superintendent, Station J. Philadelphia Electric Co., Delaware & Robbins St., Philladelphia, Pa.

GROFF, VERNON RUPERT, Electrician, Pennsylvania Water & Power Co., Holtwood; res., 246 Pine St., Steelton, Pa.

*HALL, NELSON, Designing Engineer, Fisher Electrical Works; res., 153 Howard St., Detroit, Mich.

Digitized by Google

HARRIS, JOHN BAKER, Jr., Sales Engineer, Pittsburgh Transformer Co.; res., 101 S. Harrison Ave., Bellevue, Pittsburgh, Pa.

HEALY, EDWIN S., Resident Engineer, Pacific Power & Light Co., Portland, Ore.

HENDERSON, ROBERT MOSS, Electrician, National Pipe & Foundry Co., Attalla; res., 2720 Hanover Circle, Birmingham, Ala.

JARRETT, LE GRAND, Engineer in charge Life Test Dept., Westinghouse Lamp Co., Bloomfield, N. J.

KICHLU, KUNJ BEHARI, Ford Motor Co.; res., 140 Avalon Ave., Highland Park, Mich.

KUBO, KENICHI, Assistant Engineer, Inawashiro Hydro Electric Power Co., Tokyo; res., Odera, Fukushimaken, Japan.

LEVY, KARL, Manager, Panama Telephone Co., Colon, R. P.

LOPEZ, JOAQUIN ANTHONY, Superintendent, Electrical Dept., United Fruit Co., Banes (Oriente), Cuba.

LYONS, EDWARD J., Power Inspector and Engineer, Central Illinois Light Co., Peoria, Ill.

MCLAUGHLIN, CHARLES FINLEY, Electrical Engineer and General Inspector, Arkansas Actuarial Bureau; res., 902 S. Scott St., Little Rock, Ark.

MONTEITH, VICTOR ST. CLAIR, Commercial Engineering, C. H. Spangles Electric Co.; res., 21 Jonathan Ave., Hagerstown, Md.

MOORE, SAMUEL E., St. Louis Rep., Mississippi River Power Co.; res., 5667 Von Versen Ave., St. Louis, Mo.

NOOME, CORNELIS, Manager, Naamlooze Vennootschap, Provinciale Utrechtsche Electriciteits Maaschappy, Brigittenstraat 20, Utrecht, Holland.

PERSONS, LAWRENCE MARSTON, Engineer, Reynolds Electric Co., 420 S. Talman Ave., Chicago, Ill.

PEYINGHAUS, ROBERT, Chief Electrician, Wilt Twist Drill Co.; res., 376 Argyle Rd., Walkerville, Ont.

PFLAUM, RAYMOND J., Draughtsman, Engineering Dept., Anaconda Copper Mining Co.; res., 518 Maple St., Anaconda, Mont.

PIERCE, CHARLES A., Electrical Contractor, 143 Normal Ave.; res., 106 Normal Ave., Buffalo, N. Y.

RODGERS, CHARLES, Engineer, Siemens Bros. Dynamo Works Ltd., Palace Place Mansions, Kensington Court, London, W. 8, England.

ROHDE, ARNO A., Electrical Engineer, Lehigh Portland Cement Co., Metaline Falls, Wash.

SCHENCK, SAMUEL B., Railway Engg. Division, Westinghouse Elec. & Mfg. Co., E. Pittsburgh; res., 711 Mill St., Wilkinsburg, Pa.

SCHWARTZ, WILLIAM B., Division Plant Engineer's Office, American Tel. & Tel. Co., 1422 Hurt Bldg., Atlanta, Ga.

SHRADER, WILLIAM M., Chief Electrician, Standard Aniline Products Inc., Wappingers Falls, N. Y.

SLEPIAN, JOSEPH, Research Engineering, Westinghouse Electric & Mfg. Co., East Pittsburgh; res., 7945 Madeira St., Wilkinsburg, Pa.

SMITH, HERBERT EDWARD, Foreman, Service Dept., Connell-McKone Co., 109 Brookline Ave., Boston, Mass.

SPENCER, BURT KELLOGG, Sargent & Lundy; res., 1814 W. 108th Place, Chicago, Ill.

STANNARD, JAY L., Consulting Civil Engineer, 504 Selling Bldg.; res., 415 E. 17th St. N., Portland, Ore.

STRICKLAND, A. L., City Electrician, Municipal Electric Power & Light Dept., City Hall, Ashland, Ore.

TIFFANY, W. ERNEST, Chief Inspector, Division Telegraphs & Telephones, Public Service Commission, 58 N. Pearl St., Albany, N. Y.

VOGEL, HAROLD F., Gas Analyst, New Merchant Mills, Bethlehem Steel Co.; res., 1005 Delaware Ave., S. Bethlehem, Pa.

WALKER, ERNEST T., Electrician, National Electrical Supply Co.; res., 1315 Delafield Pl. N. W., Washington, D. C.

Digitized by Google

WALKER, WALTER JENNINGS, Commercial Engineer, General Electric Co.; res., 6 Backus St., Schenectady, N. Y.

WARDEN, RALPH MURDOCH, Electrician, Electrical Dept., E. I. du Pont & Co., City Point, Va.

WEISS, JOSEPH, Meter Dept., New York Edison Co., 140th St. & Rider Ave., New York; res., 49 India St., Brooklyn, N. Y.

*WISE, LYLE D., Electrician, Fort Mills Electric Railway, Fort Mills, Corregidor Island, P. I.

WOOD, BERTRAM, Electrical Engineer, Electrolytic Zinc Co. of Australia, Ltd., Hobart, Tasmania.

WORK, LEONARD, Electrical and Mechanical Engineer, 562 Bourse Bldg., Philadelphia, Pa.

WORRALL, Robert H., Engineering Dept., Marconi Wireless Telegraph Co.; res., 121 2nd Ave. East, Roselle, N. J.

*WRIGHT, JOHN EDWARD, Manager, Lincoln County Light & Power Co., Carrizozo, New Mex.

Total 55.

*Former enrolled Students.

ASSOCIATES REELECTED OCTOBER 8, 1917

BONNARJEE, B. C., Harrison Road Post, Calcutta, India.

HOOKER, DUNCAN C., Assistant Electrical Engineer, Johns-Pratt Co., Hartford; res., Farmington, Conn.

SLOCUM, WINTHROP WALLACE, Manager, Gainaday Elec. Store, Pittsburgh Gage & Supply Co.; res., 1212 Wightman St., Pittsburgh, Pa.

SNYDER, FREDERICK TITCOMB, President, Electric Furnace Corp., 53 Jackson Blvd., Chicago; res., Oak Park, Ill.

MEMBERS ELECTED OCTOBER 8, 1917

ALBRECHT, GEORGE MORITZ, First Assistant Examiner, U. S. Patent Office; res., 1116 Monroe St. N. W., Washington, D. C.

FRERET, A. L., Electrical Engineer, Tennessee Coal, Iron & Railroad Co., Birmingham; res., 501 40th St., Ensley, Ala.

PILLOID, JAMES J., Division Plant Engineer, American Telephone & Telegraph Co., 212 W. Washington St., Chicago, Ill.

STRYKER, BURDETT, General Superintendent of Plant, Bell Telephone Co. of Penn., 1631 Arch St.; res., 5501 Wayne Ave., Philadelphia, Pa.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its regular monthly meeting, held on October 1, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

LYON, JESSE D., Consulting Engineer, Cincinnati, O.

To Grade of Member

DUFFY, FRANK J., General Foreman, Electrical Dept., D. L. & W. R. R., Scranton, Pa.

EMBREE, CLAYTON J., Office Engineer, Panama Canal, Balboa Heights, C. Z.

FULLER, LEONARD FRANKLIN, Chief Electrical Engineer, Federal Telegraph Co., San Francisco, Cal.

TRANSFERRED TO THE GRADE OF FELLOW OCTOBER 8, 1917

BLISS, WILLIAM LORD, Chief Engineer, U. S. Light & Heat Corp., Niagara Falls, N. Y.

MCGOVERN, WILLIAM R., Chief Engineer, Central Group of Bell Telephone Cos., Chicago, Ill.

TRANSFERRED TO THE GRADE OF MEMBER OCTOBER 8, 1917

AGEE, HOWARD H., Engineer, D. C. & Wm. B. Jackson, Philadelphia, Pa.

ARTHUR, WILLIAM, Electric Railway Engineer, New Haven, Conn.

Digitized by Google

CHAPMAN, A. P., Supt. Power & Repairs, Ludlow Manufacturing Associates, Ludlow, Mass.

CRYDER, Ross W., Superintendent, Lighting & Power Div., Porto Rico Railway, Light & Power Co., San Juan, Porto Rico.

DEAN, HAROLD C., Assistant to President, New York & Queens Electric Light & Power Co., Long Island City, N. Y.

DRABELLE, JOHN MITCHELL, Electrical Engineer, Iowa Railway & Light Co., Cedar Rapids, Ia.

HUCH, OTTO F., Engineer, with A. C. Wood, Philadelphia, Pa.

MARX, ROLAND G., Electrical Engineer, Palo Alto, Cal.

REES, HARRY P., Instructor in Power Plant Practice, Wentworth Institute, Boston, Mass.

ROSENBLATT, GIRARD B., Engineer in Charge, Mining Div., Westinghouse Electric & Mfg. Co., Salt Lake City, Utah.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before November 30, 1917.

Allen, H. V., (Member), New York, N. Y.
Bailey, J. B. Lafayette, Ind.
Bennison, L. C., Waddamana, Tasmania
Beyer, J. W. Pullman, Wash.
Broughall, G., (Member), London, England.
Carman, E. H., Jr., Atlanta, Ga.
Clarke, C. J., New York, N. Y.
Clarke, H. O., Jr., (Member), Houston, Tex.
Clifton, H. E., Schenectady, N. Y.
Cornelius, C. C., St. Louis, Mo.
Coxe, F. E., Burlington, N. C.
Critchfield, R. M., Pittsburgh, Pa.
Cunha, M. R. de F., Manchester, England
Curtis, L. M., Rugby, England
Davis, G. E., Schenectady, N. Y.
Dickson, F. C., Tampa, Fla.
Dodge, H. F., New York, N. Y.
Donoghue, J. E. (Member), Sidney, Australia
Doolittle, F. M., New Haven, Conn.
Dustin, C., Latouche, Alaska
Eltringham, R. L. (Member), San Francisco, Cal.
Evans, G. H., Waddamana, Tasmania
Gledhill, J. W., Newark N. J.
Harvey, E., New York, N. Y.
Helm, E. G., Martinburg, W. Va.
Hoadley, G. L., (Member), Chicago, Ill.
Howard, T. W., Schenectady, N. Y.
Kappeyne, J., (Member), Washington, D. C.
Levering R. W., Lafayette, Ind.
Lloyd, R.M. (Member), New York,N.Y.
Mac Lachlan, A., Detroit, Mich.
Massey, M. F., Washington, D. C.
McRae, W. R. (Member), Toronto, Ont.
Metzger, G. C., Somerset, Wis.
Moas, B., Jr., Havana, Cuba
Nagashio, H., Tokyo, Japan
Nelson, J. R., Springville, Cal.
Nordstrom, J. F., Philadelphia, Pa.
Nugent, H. M., Yonkers, N. Y.
O'Connell, J., Jr., Camp Mead, Md.
Ousler, G. W. Pittsburgh, Pa.
Perry, E. B., Boston, Mass.
Perry, A. M. (Member),New York,N.Y.
Prins, P., Baltimore, Md.
Rayner, D. D., Wolverhampton, England
Robinson, R. B., Duquesne, Pa.
Rogers, C. E., Montreal, Que.
Shipman, C. F., New York, N. Y.
Silberzveig, L., Barcelona, Spain
Simpson, E. L., Ft. Wayne, Ind.
Soi, M. R., Delhi, India
Spraragen, W., Stillwater, Okla.
St. Clair, B. W., West Lynn, Mass.
Stockle, E. R. (Member), Milwaukee, Wis.
Testard, P., Hollinwood, England

Digitized by Google

Utley, T. M., Superior, Wyo.
Wellhouse, F. J. (Member), Boston, Mass.
Werner, H. G., Philadelphia, Pa.
Williamson, J., Detroit, Mich.
Wilson, K. B., Chicago, Ill.
Wolcott, H. L., Nobel, Ont.
Wootton, T. W., Waddamana, Tasmania
Wright, E. A. (Member), Bluefields, Nicaragua
Total 63

STUDENTS ENROLLED OCTOBER 8, 1917

9126 Widell, B. A., Stanford University
9127 Spilman, J. M., N. Y. Elec. School
9128 Glover, C., N. Y., Elec. School
9129 Lehr, G., Jr., Penn. State College
9130 Derr, P. J. F., Penn. State College
9131 Billig, H. A., Penn. State College
9132 Bandelier, G.E., Okla.A.& M.Coll.
9133 Eastom, F., Univ. of Colorado
9134 Mechling, E. B.,Univ. of Colorado
9135 Vincent, J. T., Univ. of Colorado
9136 Tomlinson, C. M., Penn. State College
9137 Milcke, A. W., Yale University
9138 Nevitt, G. P., Yale University
9139 Long, R. E., Ohio Northern Univ.
9140 Pike, N., Throop Coll. of Tech.
9141 Alholm, A., Ohio Northern Univ.
9142 Ferlic, A. J., Ohio Northern Univ.
9143 Hipsher, M. F., Ohio Northern Univ.
9144 Brace, G.R., Ohio Northern Univ.
9145 Andres, P. M., Univ. of Kentucky
9146 Adkins, W. K., Univ. of Kentucky
9147 Brittain, J. A., Univ. of Ky.
9148 Cooper, J. W., Univ. of Ky.
9149 Davis, R. M., Univ. of Ky.
9150 Dearborn, E. R., Univ. of Ky.
9151 Ellis, D. R., Univ. of Ky.
9152 Goosman, K. W., Univ. of Ky.
9153 Hedges, J. M., Jr., Univ. of Ky.
9154 Henry, H. M., Univ. of Ky.
9155 Jackson, G. L., Univ. of Ky.
9156 Maddox, J. D., Univ. of Ky.
9157 McCormick, C. E., Univ. of Ky.
9158 McDougle, W. D., Univ. of Ky.
9159 Milward, H. L., Univ. of Ky.
9160 Nicholoff, C., Univ. of Ky.
9161 Parks, H.. Univ. of Ky.
9162 Peak, T. E., Univ. of Ky.
9163 Russell, B. B., Univ. of Ky.
9164 Costelloe, W. H., Mass. Inst.Tech.
Total 39.

ADDRESSES WANTED

Any reader knowing the present address of any of the following members is requested to communicate with the Secretary at 33 West 39th Street.

Harry H. Blades
(former address)
70—12th St. South,
Minneapolis, Minn.

Charles H. Feige
(former address)
149 West 74th St.,
New York, N. Y.

William F. Gauss
(former address)
5510 Ellsworth Ave.,
Pittsburgh, Pa.

Sydney J. Hurd
(former address)
4433 Prairie Ave.,
Chicago, Ill.

Wm. P. Lewis
(former address)
Cohoes Elec. Power Co.
Cohoes, N. Y.

Milan S. Mitrovitch
(former address)
Union Powder Co.
Parlin, N. J.

Douglas R. Moffatt
(former address)
774 Coplin Ave.,
Detroit, Mich.

Sulpen Sully
(former address)
1723 East Boulevard,
El Paso, Texas

Ernest A. Thiele
(former address)
25 Faber St.,
Port Richmond, N. Y.

C. A. Thomsen
(former address)
Tri-State College,
Angola, Ind.

Digitized by Google

PERSONAL

J. H. BARKER for eight years Manager and Sales Manager of the New York office of the Diehl Manufacturing Co. is now representing the Roth Bros. & Company of Chicago and has opened an office at 95 Liberty St., New York.

RAY K. HOLLAND, formerly with Gardner S. Williams, Consulting Engineer, is now associated with the firm of Holland, Ackerman & Holland, Consulting Engineers, who have opened offices in Ann Arbor, Michigan and Chicago, Illinois.

L. O. VESER, who for the past two and one-half years has been Electrical Superintendent of the Aluminum Co. of America and the St. Lawrence River Power Co. at Massina, N. Y., has resigned to accept a position on the engineering staff of the Electric Bond and Share Co., 71 Broadway, New York.

H. H. BARTER, engineer and technical director of the Triangle Film Corporation plant at Culver City, Cal., has accepted a call to one of the most responsible executive positions in the American International Shipbuilding Corporation of Philadelphia, which is the active agent for the United States Shipping Board Emergency Fleet Corporation.

PROFESSOR JOHN FAY WILSON has accepted the position of Associate Professor of Electrical Engineering at the University of Southern California in Los Angeles. Professor Wilson occupied for five years a similar position at the University of Michigan, and during the past year at Queens University, Kingston, Canada. He is the author of "Essentials of Electrical Engineering" and "Dynamo Laboratory Outlines".

H. S. HALEY, member of the firm of Leland and Haley, Consulting Mechanical and Electrical Engineers, of 58 Sutter St., San Francisco, Cal., is at present at the Llewellyn Iron Works, Los Angeles, in the interest of the U. S. Shipping Board Emergency Fleet Corporation, on one of the largest marine engines and boilers contract placed on the Pacific coast. Mr. Haley still retains his interest in the firm of Leland and Haley.

LIEUTENANT WARNER H. PEBERDY, of the Royal Naval Air Service, an Associate of the Institute, and formerly with the Electric Bond and Share Co., New York, is reported killed in Mesapotamia.

Lieutenant Peberdy was sent out to wreck some bridges near Bagdad and did not return. He knew that the service was hazardous, as he wrote a farewell letter before setting out.

ARTHUR WILLIAMS, General Commercial Manager of the New York Edison Company, was appointed Federal Food Administrator for New York City on October 24. He will work in close cooperation with the various committees and commissions and the Federal agent for the State in the solving the food problems of this city. Mr. Williams up to the present has been Chairman of the U. S. Food Administration campaign to enlist New York women as aids to the Food Administrator.

Mr. Williams has been decorated by France as an officer of L'Instruction Republique and by the King of Spain, who made him a Knight of St. Isabel. During the Spanish-American war he served as an officer in charge of mine laying in New York Harbor. He is a Fellow of the A. I. E. E., Past President of the N. E. L. A., the Association of Corporation Schools, the Association of Edison Illuminating Companies, the Electric Vehicle Association of America and the New York Electrical Society.

Digitized by Google

OBITUARY

PERCY L. COBB, electrical engineer, connected with the Interstate Commerce Commission, Division of Valuation of Railroads, Washington, D. C., died on Oct. 11, 1917. Mr. Cobb was a graduate of Stevens Institute of Technology and had served with both the Pennsylvania and the N. Y. W. & B. R. R. He was an associate in the A. I. E. E.

JOHN K. ROBINSON, electrical engineer, for many years representative of the Westinghouse Electric Export Company on the western coast of South America, died suddenly at his summer home at Naples, Maine, on Sept. 7, 1917. Mr. Robinson, born in Chicago April 3, 1866, was a graduate of the Boston Institute of Technology and had attained the grade of Fellow in the A. I. E. E.

DR. EUGENE F. ROEBER, editor of Metallurgical and Chemical Engineering, and one of the founders of the American Electro-Chemical Society died on October 18, 1917 at his home in East Orange, N. J. Mr. Roeber was born in Pergau, Germany in 1867 and came to this country in 1894. He was a member of the American Institute of Mining Engineers, the American Chemical Society, the American Institute of Chemical Engineering, the Society of Chemical Industry, the Chemist's Club and the A. I. E. E.

MR. KARL VON KROGH, Consulting Electrical Engineer of the firm of Nissen & Von Krogh Christiania, Norway was recently killed in Sweden while conducting an overspeed test on a generator. The machine exploded.

Mr. Von Krogh was born in 1876 in Norway and received his early education there and in Germany. In 1900 he entered the employ of the British Schuckert Electric Co., London, and shortly afterwards went with Siemens & Halske, Berlin. In 1902 he undertook experimental work for the Allgemeine Electricitats Gesellschaft. In 1904 he became Engineer with the British Westinghouse Co., of Manchester with whom he held successively many important positions.

Mr. Von Krogh was chairman of the sub-committee on standardization of the Norwegian National Committee of the International Electrotechnical Commission, and while in the United States in October 1916 he accepted an invitation from the Institute's Standards Committee to attend its meeting in Philadelphia and give the committee the benefit of his suggestions and criticisms of the standardization rules, which were then being revised.

Mr. Von Krogh became an Associate of the Institute on October 8, 1909, and was transferred from the grade of Associate to the grade of Fellow on May 18, 1917.

Digitized by Google

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From September 9 to October 1, 1917)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made. These are taken either from the preface or the text of the book.

All the books listed may be consulted in the United Engineering Society Library.

Business Law for Engineers.

By C. Frank Allen. Part I, Elements of Law for Engineers, Part II Contract Letting. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 431 pp., 9x6 in., cloth, $3.

The purpose of the book is to give the engineer a sufficient understanding of important fundamental features of law, so that he may have some idea of when or how to act himself and when to seek expert advice.

The author has had experience as a civil engineer and has also practised law.

Business Statistics.

Edited by Melvin T. Copeland. Cambridge, Harvard University Press; Lond., Humphrey Milford, Oxford University Press, 1917. 12+696 pp., 3 diagrams, 9x6 in., cloth, $3.75.

A collection of articles on the subject, illustrating the methods of collecting and presenting the statistics used in mercantile and manufacturing businesses, and the use made of them, prepared primarily for purposes of instruction in the Harvard Graduate School of Business Administration. Contents: Statistical Methods; Statistical Indices of Business Conditions; Sales and Advertising Statistics; Factory Statistics; Statistics for the Chief Executive.

Corporate Organization and Management.

By Thomas Conyngton. Revised by H. Potter. N. Y., The Ronald Press Co., 1917. 26+778 pp., 9x6 in., cloth, $5.

A combination of the author's former books, "Corporate Management," and "Corporate Organization", in which duplicated material has been deleted and the remaining matter thoroughly modernized. Intended to furnish a convenient manual of corporation law and procedure for lawyers, corporation officials and business men.

Examination of Water.

Chemical and Bacteriological. By William P. Mason. 5th ed. rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 186 pp., 9 illus., 7 pl., 8x5 in., cloth, $1.25.

Various methods given in former editions have been replaced by others more suited to modern practise, and the analytical methods have been harmonized with the recommendations of the 1917 report of the American Public Health Association.

Electrical Machinery.

Principles, Operation and Management. By Terrell Croft. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 318 pp., 302 illus., 8x6 in., cloth, $2.

The author believes that there are certain things which the average man should know and that these may be presented without employing difficult mathematics. In his book he has tried to explain the theoretical principles, operation and management of electric generators, motors, etc., in a way which will be useful to those engaged in practical electrical work.

History of Transportation in the United States Before 1860.

Prepared under the direction of Balthasar Henry Meyer by Caroline E. MacGill and a staff of collaborators. Washington, Carnegie Institution, 1917. 11+678 pp., 6 maps, 10x7 in., paper, $6.50.

The Division of Transportation in the Department of Economics and Sociology of the Carnegie Institute of Washington presents this study of early American roads, railroads and waterways as a contribution to American economic history, not as a completed study. An extensive bibliography is included, as well as colored maps showing the railroads in 1840, 1850 and 1860, present and abandoned canals, and the navigable rivers.

Is Civilization a Disease?

By Stanton Coit. Bost. and N. Y., Houghton Mifflin Co.; The Riverside Press, Cambridge; 1917. 136 pp., 7x5 in., cloth, (gift of the University of California Press).

One of a series of essays on various phases of the moral law in its bearing on business life under the new economic order, delivered at the University of California and known as the Barbara Weinstock Lectures on the Morals of Trade.

Digitized by Google

MILITARY PREPAREDNESS AND THE ENGINEER.

A Handbook for the Civilian Engineer By Ernest F. Robinson. 2d ed. N. Y., The Clark Book Co., 1917. 244 +361 pp., 132 illus., 7x4 in., leather, $2.

Written to place before the engineers of America as accurate an idea as possible of the opportunities and limitations that will confront the civilian engineer who is called to the colors, and to present the salient points of military engineering in the language with which he is familiar.

This edition has been revised in the light of recent European experience, and considerable new matter has been added on field fortifications, wire entanglements, and the organization of captured positions.

MODERN MACHINE SHOP.

Construction, Equipment and Management. A Comprehensive and Practical Treatise on the Economical Building, the Efficient Equipment and Successful Management of the Modern Machine Shop and Manufacturing Establishment. A work for the architect, engineer, manufacturer, director, officer, accountant, superintendent and foreman. By Oscar E. Perrigo. 2d ed. rev. and enl. N. Y., The Norman W. Henley Publishing Co., 1917. 384 pp. 219 illus., 9x6 in., cloth, $5.

Four new chapters have been added, treating of new developments in shop management. These deal with methods of increasing the efficiency of men and machines, with the relation of the overhead burden to the flat cost and with manufacturing cost systems.

OFFICIAL AUTOMOBILE BLUE BOOK 1917.

Standard Road Guide of America. Volume A, New York City and the Metropolitan District Embracing a Radius of 100 Miles from Columbus Circle. N. Y., Chicago, San Francisco, The Automobile Blue Book Publishing Co.; (copyright 1917) 624 pp., illus. 1 map, 9x5 in., leather, $3.

The Blue Books cover the entire United States and Southern Canada in eleven volumes (see insert between pages 160 and 161). They tell you where to go and how to get there, giving complete maps of every motor road, running directions at every fork and turn, with mileages. All points of local or historical interest, state motor laws, hotel and garage accommodations, ferry and steamship schedules and rates. A veritable motorist's encyclopedia.

PARALLEL TABLES OF SLOPES AND RISES.

In Combination with Diagrams of Slopes and Rises and Other Tables for Bridge and Structural Engineers, Draftsmen, Checkers, Templet Makers, Builders, and Vocational Schools. By Constantine K. Smoley. N. Y. and Lond., McGraw-Hill Book Co., 1917. 34+330 pp., 33 illus., 8 pl., 7x5 in., leather, $4.00

Essentially an extension of Smoley's "Tables", this book consists of reprints from that volume, together with tables of slopes and rises. Differs from the former work, which is in the nature of a general calculator, in being concerned only with the solution of right triangles when one side and the bevel of the hypothenuse are known. Enables the calculator readily to determine the dimensions and bevels of the members of a structure, and also to lay out the joints and determine the dimensions of the material.

PRACTICAL WIRELESS TELEGRAPHY.

A Complete Text Book for Students of Radio Communication. By Elmer E. Bucher. N. Y., Wireless Press, Inc., (copyright 1917) 322 pp., 323 illus., 9x6 in., cloth, $1.50.

After an exposition of those fundamentals of electricity which the telegraphist should know, the book describes the circuits of practical wireless sets and explains the basic principles of the apparatus associated with them. The author has chosen for description that apparatus which is most widely in commercial use.

RESEARCHES OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM, VOLUME III. OCEAN MAGNETIC OBSERVATIONS 1905–1916.

and Reports on Special Researches. By L. A. Bauer with the collaboration of W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. Washington, Carnegie Institution of Washington, 1917. 447 pp., 11x9 in., paper, $10.

This volume presents the final results of the observations made aboard the *Galilee* and the *Carnegie* during the period designated. The special reports relate to atmospheric-electric observations, and to some discussions of the ocean magnetic work. The book is the third of the series of "Researches of the Department of Terrestrial Magnetism" published by the Carnegie Institution, the former two volumes of which treated of land magnetic observation.

Digitized by Google

TEXT-BOOK OF THE MATERIALS OF ENGINEERING.

By Herbert F. Moore. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10+204 pp., 69 illus., 1 pl., 9x6 in., cloth $2.

A concise presentation of the physical properties of the common materials used in structures and machines, accompanied by brief descriptions of their manufacture and fabrication. Distinctly elementary in character. References to sources of additional information are included in each chapter.

THE COMPOSITION OF TECHNICAL PAPERS.

By Homer Andrew Watt. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 13+431 pp., 41 illus., 8x5 in., cloth, $1.50.

A systematic text-book of English composition, intended to prepare the engineering student to write successfully such papers as his vocation will demand of him. Includes numerous examples of descriptive articles, expositions of processes and ideas, reports and letters.

THE ELECTRON.

Its Isolation and Measurement and the Determination of Some of its Properties. By Robert Andrew Millikan. Chicago, The University of Chicago Press, (copyright 1917) 12+261 pp., 33 illus., 8x5 in., cloth, $1.50.

Written to present the evidence for the atomic structure of electricity, to describe some of the most significant properties of the elementary electrical unit and to discuss the bearing of these properties on the structure of the atom and the nature of electromagnetic radiation. Based on the author's researches in the Ryerson Laboratory but includes a review of the work of former and contemporary investigators.

THE FLYING BOOK 1917.

Edited by W. L. Wade. N. Y. and Lond., Longmans, Green and Co., Lond., The Aviation World Publishing Co., Ltd., 1917. 291 pp., 165 illus., 6 pl., 9x6 in., boards, $1.25.

Divided into three parts. Part one includes a number of brief articles on the design, control and use of airplanes and engines; the present flight records and alphabetical lists, with silhouettes and brief descriptions of engines, airplanes of today and airplanes of historic interest. Part two contains directories of aeronautical societies and of British, American, French and Italian firms; and a biographical dictionary of aviators and manufacturers. Part three, on military and naval aviation, includes the British honor list for 1916; a record of the work of the Zeppelin and a diary of the events of 1916; a list of aeronautical publications, a glossary of terms and various tables complete this handbook.

THE PRINCIPLES OF IRON FOUNDING.

By Richard Moldenke. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 10+517 pp., 45 illus., 9x6 in., cloth, $4.

A study of the principles underlying all the processes involved in the art of iron-founding, and an attempt to elucidate them, in the light of present metallurgical knowledge. Contents: Introduction; Industrial Status of the Foundry; Foundry Organization; Outline of Iron Metallurgy; Outline of Iron-Making Processes; Properties of Cast Iron; Classification of Castings; Foundry Raw Materials; The Technology of Combustion; Melting Processes; Mixture-Making; Testing of Cast Iron; Glossary of Foundry Terms; Appendix.

THEORY AND CALCULATIONS OF ELECTRICAL APPARATUS.

By Charles Proteus Steinmetz. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 22+480 pp., 227 illus., 9x6 in., cloth, $4.

Discusses the most important characteristics of the numerous apparatus which have been devised and have found their place in the theory of electrical engineering. The work is a continuation, or rather a part of, the author's "Theory and Calculation of Alternating-Current Phenomena". The matter appearing in earlier editions of that work has now been expanded and distributed into three volumes: "Alternating-Current Phenomena", "Electric Circuits" and "Electrical Apparatus". Contents: Speed Control of Induction Motors; Multiple Squirrel-Cage Induction Motor; Concatenation; Induction Motor with Secondary Excitation; Single-Phase Induction Motor; Induction Motor Regulation and Stability; Higher Harmonics in Induction Motors; Synchronizing Induction Motors; Synchronous Induction Motor; Hysteresis Motor; Rotary-Terminal Single-Phase Induction Motors; Frequency Converter or General Alternating-Current Transformer; Synchronous Induction Generator; Phase Conversion and Single-Phase Generation; Synchronous Rectifiers; Reaction Machines; Inductor Machines; Surging or Synchronous Motors; Alternating-Current Motors in General; Single-Phase Commutator Motors; Regulating Pole Converter; Unipolar Machines; Review; Conclusion.

TIMBER FRAMING.

By Henry D. Dewell. San Francisco, Dewey Publishing Co., 1917. 275 pp.,

Digitized by Google

112 illus., 9x6 in., cloth, $2. (gift of the Mining and Scientific Press)

Presents the result of eleven years' experience in the design and superintendence of timber construction. Intended to supplement standard text-books on the subject by bringing into correlation the drafting-room design and the requirements of the field. Originally appeared in "Western Engineering" but has been revised and enlarged.

UTILIZATION OF PYRITE OCCURRING IN ILLINOIS BITUMINOUS COAL.

University of Illinois Bulletin, vol. 14, no. 51, August 20th, 1917. By E. A. Holbrook. Urbana, University of Illinois, 1917. 46 pp., 14 fig., 9x6 in., paper 20 cents.

This pamphlet, which is circular no. 5 of the Engineering Experiment Station, is an outline of laboratory experiments performed on a commercial scale in the mining laboratory of the University with a view to developing a simple process for the economic recovery of the pyrite occurring with this coal and now commonly rejected as worthless. Plans of a suitable plant and estimates of its construction and operating costs are given, together with a description of the tests which lead to its design. The author is convinced that the process is commercially feasible.

WHAT A GEOLOGIST CAN DO IN WAR.

Prepared by R. A. F. Penrose, Jr. for the Geological Committee of the National Research Council. Philadelphia, J. B. Lippincott Co., 1917. 28 pp., 6x4 in., cloth, (gift of the author)

Suggests the services which he can render in the selection of camp sites, ground for artillery positions, trench and tunnel locations, and other military operations.

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-281. Wanted: Foreman to take full charge of testing, repairing and examining division of electrical department of concern of high repute in the east. Possibilities for advancement depend strictly upon the man's ability to handle the work entrusted in his care. Please give details of experience, nationality, salary expected, etc.

V-282. Electrical engineer, with experience in designing transformers for all kinds of work, such as power, furnace precipitation, testing, X-ray, etc. Give details of experience and salary desired.

V-283. Draftsman, original designer capable of taking initiative in the design of high tension electrical power transmission and sub-station work. 32,000 volts. Location, mining district central Canada. Salary $190. per month. When replying confine statement of experience to this particular line and be specific. State age, nationality and if married or single.

V-284. Electrical Draftsman wanted, experienced with central station and transformer sub-station layouts. State full qualifications. Good working conditions and future promise.

V-285. Several positions open with the development department of a growing corporation, handling electrical precipitation processes. The work calls for technical graduates, preferably electrical, with three or four years experience, resourceful and able to carry on original work, which will be done in the vicinity of New York City. In answering give full information as to age, education, experience and salary desired.

V-286. Young technical graduate in electrical engineering who wishes to

Digitized by Google

follow partly commercial rather than wholly technical lines is wanted by one of the most successful manufacturing companies in its branch of the electrical industry (not machinery). Must possess initiative, energy, thoroughness, reliability, as development and advancement of the individual will depend upon these qualities.

V-287. Opportunity for several young technically trained men, preferably with some practical experience, with public service commission of New York. Salary about $90. per month to start. Please give particulars as to training, age and experience.

V-288. A private school in the middle west has an opening for professorship in mechanical engineering. Exceptional opportunities for advancement. Salary dependent on experience and ability of applicant. Investment in institution desirable but not essential. Give full information and references relating to character, education and teaching experience.

V-289. Electrical Draftsman wanted, familiar with factory power distribution and power setting layout. Good position for capable man. Call or write, stating experience, whether married or single, age and salary desired in first letter.

V-290. Wanted, three technical graduates for steam engineering and general testing. Headquarters Pittsburgh. Work covers steel mills in Pennsylvania, Ohio, West Virginia and Indiana.

V-291. Wanted: Electrical draftsman for six or eight weeks work. Location New York.

V-292. Wanted: Technical graduates with several years practical electrical engineering experience of some kind to act as instructors for recruits for Signal Corps. Duties to be (a) to examine the men in electrical subjects; (b) to give laboratory instruction to small groups in the laboratory; (c) to assist in planning and organizing the course of instruction.

One of these vacancies requires a technical graduate who has specialized in wireless work and who has had a few years experience in some of its applications, to assume general charge of laboratory apparatus as regards its maintenance, attending to repairs, ordering new equipment, etc. Will be required to give class-room instruction only, but practical knowledge and experience are essential, as well as theoretical. Persons interested in either of these positions are requested to communicate at once with: J. R. Benton, Dean of the College of Engineering, University of Florida, Gainesville, Fla., giving brief statement of education, experience, names of references, how soon available, and salary desired.

V-293. Draftsman with sufficient experience to enable him to lay out machinery in new plants, including the making of drawings covering electric light and power systems. Permanent position in Engineering Department. Prefer man with chemical plant experience, or who has done drafting for consulting engineer. State qualifications and past experience fully. Applicant must be in possession of technical training. Salary $1300. to start. Location southern Ohio.

V-294. Power Superintendent is needed to take charge of a power plant near New York City, consisting of 2600 B. H. P. of stoker-fired B. and W. boilers burning anthracite; 2500 B. H. P. of B. and W. waste heat boilers; 15 Prime movers, steam turbines and Corliss engines, up to 1500 I. H. P. driving D. C. generators and air compressors. State nationality, age, education, experience in full, and salary expected.

MEN AVAILABLE

842. Electrical and mechanical engineer, technically educated, age 32, married, desires connection with industrial firm where ability and service will insure advancement. Twelve years' experience in design, construction and operation of public utility and industrial power plants and in equipment of merchant steamships. Present position, chief engineer for large mining company.

843. Electrical Engineer, technical education, ten years experience in power station and sub-station design and construction, and large light and power installation, desires responsible position in design, field or consulting work. At present employed but available at short notice.

844. Electrical Engineer desires to locate in Michigan or Wisconsin. College course, machine shop and foundry apprenticeship with well known engine works, one year as plant operator, 15,000 kv-a. units, four years superintendent of power plants and construction in Iowa. Now holding responsible position in Chicago.

845. Technical electrical graduate (1916). General Electric test experience, is in position to devote 15 to 20 hours a week to any work, outside of business hours. Am capable of doing thorough

Digitized by Google

and clean-cut work. Here is the opportunity to have that work done in the right way.

846. Graduate Electrical Mechanical Engineer. Ten years broad successful experience with large railroad and manufacturers, construction, operation and maintenance power plants, and power application. Can produce results measured in loyalty, good will, and dollars and cents for progressive concern. Salary $4500. Available after 30 days notice to present employer.

847. Electrical-Mechanical Engineer, experienced in power plant construction and operation, construction and maintenance of transmission systems, and general industrial applications of electric power. At present in charge of public utility operating steam electric power plant and high tension distribution. Salary $2200. Married.

848. Industrial Research Engineer, with seven years' experience desires position in experimental or development work. Technical graduate and postgraduate, good draftsman, familiar with use of tools and instruments, possesses natural inventive ability, wide knowledge of the properties of materials and proficient in chemistry and mathematics. Age 32, married.

849. Operating Engineer. Has held positions of superintendent of distribution and general superintendent in cities up to 300,000 inhabitants. Practical experience in meter and line construction work before entering college. Executive ability, technical graduate and full member A. I. E. E. Age 33. Permanent operating position desired as general superintendent, superintendent distribution, power engineer.

850. Manager or superintendent, technical and practical, nineteen years experience as electrical engineer, commercial manager electric light power and railway company. Experience covers manager construction, engineering, and operation of distribution and transmission system, steam and hydro power plants, commercial engineer, reorganization of utilities. Age 38.

851. Electrical-Mechanical Engineer wishes position with industrial or public utility company or engineering firm. Broad experience as executive on construction and operation street railways, power plants, transmission and distribution. Several years in South America, familiar with Spanish language.

852. Electrical-Mechanical Engineer, available February first, thirty-three, single, technical education, ten years' practical and executive experience power plant design, installation and operation also industrial power application in Pulp Mill, Coal Mine, Gold Mine and Sawmills. Will accept right position at home or abroad. Correspondence invited.

853. Electrical Engineer, technical graduate, age 33, married. Four years' experience testing electrical machinery and steam turbines. Six years in charge construction and operation of steam turbine plant, transmission lines, substations and hoisting equipment for large coal company.

854. Executive, Vice President of operating syndicate would consider new connection presenting broader field; technical graduate; member A. I. E. E. 20 years' experience in central station and electric railway operation, electrification of industrials and ice manufacturing; expert on management, purchasing, rate making, and public relations.

855. University graduate mechanical-electrical engineer with several years engineering, executive, and manufacturing experience desires position as production or efficiency engineer. Age 33. Married. Salary $2000. per year. Available Nov. 15.

856. Experienced mechanical and electrical engineer. Age 38. American born. Eighteen years as construction superintendent. Has designed, built and erected mechanical machinery, sub-station buildings of steel and concrete, pile foundations, steam power and boiler equipment; also installed railroad and industrial apparatus motor generators, transformers, cables, pole lines and tower transmission lines. Salary $2400. Best of references.

857. University graduate, ten years mechanical and electrical experience, wishes to investigate opportunities in vicinity of New York City. Familiar with erection and operation for both steam and hydraulic power houses also shops, foundry and general equipment for mines. Five years connection with large projects abroad including position as resident engineer.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1917-1918.

PRESIDENT.

(Term expires July 31, 1918)

E. W. RICE, Jr.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1918)
JOHN J. CARTY

(Term expires July 31, 1919)
H. W. BUCK

VICE-PRESIDENTS.

(Term expires July 31, 1918)

B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON
FREDERICK BEDELL
A. S. McALLISTER
JOHN H. FINNEY

MANAGERS.

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS
E. H. MARTINDALE

(Term expires July 31, 1921)
WALTER A. HALL
WILLIAM A. DEL MAR
WILFRED SYKES

TREASURER (Term expires July 31, 1918)
GEORGE A. HAMILTON

SECRETARY.
F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

LIBRARIAN
HARRISON W. CRAVER

GENERAL COUNSEL.

PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1917.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1892-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK, 1916-17.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to October 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

E. W. Rice, Jr., Chairman,
General Electric Company, Schenectady, N. Y.
H. W. Buck, Harold Pender,
N. A. Carle, L. T. Robinson,
George A. Hamilton, C. E. Skinner.

FINANCE COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
Walter A. Hall, Charles Robbins.

MEETINGS AND PAPERS COMMITTEE

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary,
Westinghouse E. and M. Company, Pittsburgh, Pa.
B. A. Behrend, Harris J. Ryan,
W. I. Slichter,
and the chairmen of the technical committees

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
M. G. Lloyd, L. T. Robinson,
Henry H. Norris, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
80 Park Place, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller, H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 West 23rd St., New York.
William McClellan, F. L. Rhodes,
Henry H. Norris, W. I. Slichter.

SECTIONS COMMITTEE.

Walter A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
P. H. Daggett, Vice-Chairman
John B. Fisken, H. W. Flashman,
A. M. Schoen,
and the chairmen of all Institute Sections, *ex-officio.*

COMMITTEE ON STUDENT BRANCHES.

(Sub-Committee of Sections Committee.)
P. H. Daggett, Chairman,
University of North Carolina, Chapel Hill, N. C.
Alexander M. Gray, A. C. Lanier,
C. Francis Harding, Charles F. Scott.

MEMBERSHIP COMMITTEE.

H. A. Pratt, Chairman,
W. E. and M. Company, 165 Broadway, N. Y.
F. F. Barton, Wills MacLachlan,
H. Goodwin, Jr., H. R. Woodrow.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
W. E. and M. Company,
165 Broadway, New York.
H. W. Buck, P. Junkersfeld,
N. A. Carle, John W. Lieb,
John J. Carty, E. W. Rice, Jr.,
C. E. Skinner.

HEADQUARTERS COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
A. S. McAllister, F. L. Hutchinson.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, W. S. Gorsuch,
Frederick Bedell, F. C. Hanker,
Joseph Bijur, H. M. Hobart,
L. F. Blume, P. Junkersfeld,
James Burke, A. E. Kennelly,
G. A. Burnham, G. L. Knight,
N. A. Carle, F. A. Laws,
P. H. Chase, A. S. McAllister,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
William A. Del Mar, C. E. Skinner,
A. M. Dudley, N. W. Storer,
E. J. Edwards, John B. Taylor,
H. W. Fisher, R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau St., New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, A. S. McAllister,
B. A. Behrend, M. I. Pupin,
James Burke, E. B. Rosa,
John J. Carty, David B. Rushmore,
Gano Dunn, Charles F. Scott,
H. M. Hobart, Clayton H. Sharp,
John W. Lieb, C. E. Skinner,
Elihu Thomson.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, A. S. McAllister,
Gano Dunn, Schuyler Skaats Wheeler

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.

Term expires July 31, 1919.
Charles F. Brush, Chairman,
481 The Arcade, Cleveland, Ohio.
N. W. Storer, C. C. Chesney.

Term expires July 31, 1920.
Carl Hering, Harris J. Ryan,
Robert Lindsay.

Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.

Term expires July 31, 1922.
C. A. Adams, L. A. Ferguson,
S. W. Stratton.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1918.
L. T. Robinson, Harold Pender,
C. E. Skinner.

Term expires July 31, 1919.
B. A. Behrend, John J. Carty,
A. S. McAllister.

Ex-Officio.

E. W. Rice, Jr., President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to October 1, 1917.

POWER STATIONS.

Philip Torchio, Chairman,
N. Y. Edison Company, 124 E. 15th St., New York.

L. P. Crecelius,	H. S. Putnam,
W. S. Gorsuch,	F. A. Scheffler,
P. M. Lincoln,	R. F. Schuchardt,
S. A. Moss,	H. L. Wallau,
I. E. Moultrop,	W. F. Wells,

B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Company, Niagara Falls, N. Y.

A. O. Austin,	P. M. Lincoln,
J. A. Brundige,	L. C. Nicholson,
H. W. Buck,	W. D. Peaslee,
Wallace S. Clark,	D. W. Roper,
E. E. F. Creighton,	Harris J. Ryan,
H. W. Fisher,	P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman,
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,	William A. Del Mar,
A. H. Armstrong,	J. V. B. Duer,
A. H. Babcock,	John Murphy,
Reinier Beeuwkes,	Charles F. Scott,
W. H. Blood, Jr.,	H. M. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Company, Cleveland, O.
A. G. Pierce, Vice-Chairman,
2211 Farmers Bank Building, Pittsburgh, Pa.

H. W. Cope,	Charles D. Knight,
James Dixon,	A. M. MacCutcheon,
A. M. Dudley,	James M. Smith,
R. H. Goodwillie,	H. Weichsel,
A. L. Hadley,	J. B. Wiard,
C. A. Kelsey,	R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,	R. C. Powell,
C. E. Clewell,	E. B. Rosa,
J. R. Cravath,	W. D'A. Ryan,
Bassett Jones,	Clayton H. Sharp,
T. S. Perkins,	W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE

W. B. Jackson, Chairman,
Harris Trust Building, Chicago, Ill.

P. H. Bartlett,	Leavitt L. Edgar,
Philander Betts,	W. S. Gorsuch,
W. H. Blood, Jr.,	Ralph G. Hudson,
Fred A. Bryan,	A. H. Kruesi,
C. L. Cory,	Allard Smith.

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
Commonwealth Edison Company, 72 W. Adams St., Chicago, Ill.

E. E. F. Creighton,	P. M. Lincoln,
Leslie N. Crichton,	A. A. Meyer,
James C. Dow,	N. L. Pollard,
L. L. Elden,	F. E. Ricketts,
E. M. Hewlett,	Philip Torchio,

H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

F. A. J. Fitzgerald, Chairman,
Fitzgerald Laboratories, Niagara Falls, N. Y.

Lawrence Addicks,	F. A. Lidbury,
Joseph L. Dixon,	T. H. Schoepf,
I. R. Edmands,	J. A. Seede,
Carl Hering,	Willis R. Whitney.

ELECTROPHYSICS.

Frederick Bedell, Chairman,
Cornell University, Ithaca, N. Y.

H. D. Arnold,	F. W. Peek, Jr.
A. C. Crehore,	L. T. Robinson,
E. P. Hyde,	E. B. Rosa,
P. S. Millar,	C. E. Skinner.

TELEGRAPHY AND TELEPHONY.

L. F. Morehouse, Chairman,
A. T. and T. Company, 195 Broadway, New York.

E. F. W. Alexanderson,	William Maver,
R. E. Chetwood,	Kempster B. Miller,
E. B. Craft,	John Stone Stone,
M. M. Davis,	John B. Taylor,
A. H. Griswold,	J. L. Wayne.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.
D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,	Guy Hill,
M. W. Day,	O. P. Loomis,
L. A. Doggett,	G. A. Pierce, Jr.,
G. E. Edgar,	H. M. Southgate,
W. L. R. Emmet,	E. A. Sperry,
W. R. Furlong,	Wilfred Sykes,
H. L. Hibbard,	F. W. Wood.

USE OF ELECTRICITY IN MINES.

H. H. Clark, Chairman,
Bureau of Mines, 40th and Butler Sts., Pittsburgh, Pa.

Frank H. Armstrong,	R. L. Kingsland,
Graham Bright,	A. B. Kiser,
W. A. Chandler,	Charles Legrand,
F. J. Duffy,	Charles M. Means,
L. C. Ilsley,	K. A. Pauly,

H. M. Warren,

ELECTRICAL MACHINERY.

Alexander M. Gray, Chairman,
Cornell University, Ithaca, N. Y.

B. A. Behrend,	H. F. T. Erben,
A. M. Dudley	R. B. Williamson,

James Burke.

INSTRUMENTS AND MEASUREMENTS.

S. G. Rhodes, Chairman,
104 East 32nd St., New York.

P. G. Agnew,	F. V. Magalhaes,
F. P. Cox,	T. S. Perkins,

Clayton H. Sharp.

IRON AND STEEL INDUSTRY.

F. D. Egan, Chairman,
Pittsburgh Crucible Steel Co., Midland, Pa.

F. B. Crosby,	J. C. Reed,
Eugene Friedlaender,	A. G. Pierce,
E. S. Jefferies,	Wilfred Sykes,
W. C. Kennedy,	R. Tencher
D. M. Petty,	R. B. Williamson,

J. H. Wilson.

EDUCATIONAL.

E. J. Berg, Chairman,
Union College, Schenectady, N. Y.

Alexander M. Gray,	E. B. Merriam,
Charles S. Howe,	Chester W. Rice,
E. A. Loew,	C. E. Skinner,

W. I. Slichter.

Digitized by Google

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

C. O. Mailloux, John J. Carty.
Paul M. Lincoln, H. W. Buck.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

W. I. Slichter, Edward D. Adams,
Harold Pender, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

W. S. Franklin, G. W. Pierce.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney Charles W. Stone,
Calvert Townley.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON ENGINEERING COUNCIL.

H. W. Buck, N. A. Carle,
E. W. Rice, Jr., P. Junkersfeld,
C. E. Skinner.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

COMMITTEE ON GENERAL ENGINEERING, ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE.

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand.
T. P. Strickland, N. S. W. Government Railways Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
A. S. Garfield, 45 Boulevard Beausejour Paris 16 E. France.
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to October, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	Thomas C. Taliaferro, S. E. Underwriters Ass'n., Atlanta, Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L. M. Potts, Industrial Bldg., Baltimore, Md.
Boston.....Feb. 13, '03	H. M. Hope	Ira M. Cushing, 84 State St., Boston, Mass.
Chicago.....1893	Wm. J. Crumpton	C. A. Keller, Edison Building, Chicago, Ill.
Cleveland.....Sept. 27, '07	C. M. Rakestraw	C. S. Ripley, 711 Williamson Building, Cleveland, Ohio.
Denver.....May 18, '15	Norman Read	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	H. H. Higbie	H. J. Wyckoff, Detroit Edison Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne, Ind.
Indianapolis-Lafayette..Jan. 12, '12	H. O. Garman	D. J. Angus, Esterline and Angus, Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	Alexander Gray, Cornell Univ., Ithaca, N. Y.
Kansas City, Mo......Apr. 14, '16	W. F. Barnes	W. F. Barnes, Kansas City, Mo.
Los Angeles.....May 19, '08	Don Morgan	A. W. Nye, University of Southern California, Los Angeles, Cal.
Lynn.....Aug. 22, '11	J. M. Davis	R. D. Thomson, General Electric Company, West Lynn, Mass.
Madison.....Jan. 8, '09	J. R. Price	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	Arthur Simon	Soren H. Mortensen, Allis-Chalmers Mfg. Co., West Allis, Wis.
Minnesota.....Apr. 7, '02	F. W. Springer	A. B. King, Electric Machinery Company, Minneapolis, Minn.
Panama.....Oct. 10, '13	C. J. Embree	W. F. Kleene, Ancon, C. Z.
Philadelphia.....Feb. 18, '03	Nathan Hayward	H. Mouradian, Bell Telephone Co. of Penna., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	F. E. Wynne	G. M. Baker, G. E. Co., Oliver Building, Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	F. F. Brand	E. H. Branson, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	E. D. Searing	R. M. Boykin, North Coast Power Co., Portland, Oregon.
Rochester.....Oct. 9, '14	Frank C. Taylor	C. T. Wallis, 138 Fairview Avenue, Rochester, N. Y.
St. Louis.....Jan. 14, '03	A. McR. Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	L. R. Jorgensen	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	W. L. Upson	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	Charles A. Lund	J. E. E. Royer, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio.
Toronto.....Sept. 30, '03	William G. Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb.
Urbana.....Nov. 25, '02	L. V. James	A. R. Knight, Univ of Illinois, Urbana, Ill.
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co. Vancouver, B. C
Washington, D. C......Apr. 9, '03	Paul G. Agnew	J. Ernest Smith, McKinley Manual Training School, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	L. E. Tighe	F. V. Murrah, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	J. A. Douglas, P.O. Box 190, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	E. P. O'Neal	J. C. Douthit, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	R. A. Newlander	A. A. Hofgren, Armour Institute, Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	A. J. Swank	G. F. Teale, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	W. F. Eames	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio
Clarkson Col. of Tech....Dec. 10, '15	R. H. Hoyt	E. S. Parks, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	R. C. Richards	W. A. Stallings, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Robert Newman	William N. Gittings, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ of.....June 25, '14	D. Nankervis	L. J. Corbett, Univ. of Idaho, Moscow, Idaho.
Iowa State College.....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St. Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	L. N. Miller	M. H. Russell, Kansas State Agri. Col., Manhattan, Kansas.
Kansas Univ. of.....Mar. 18, '08		
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron, State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Harry C. Hartung	William Lash Lipps, 633 Parsons, Easton, Pa.
Lehigh University.....Oct. 15, '02	R. H. Lindsay	R. D. Bean, 40 N. 7th Ave., Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech.....Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	W. R. Harvey	T. W. Connant, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of.....May 16, '16	George W. Miller	Ray McKibben, University of Minnesota, Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col......May 21, '07	Roy C. Hagen	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	Oskar E. Edison, University of Nebraska, Lincoln, Nebraska...
North Carolina Col. of Agr. and Mech. Arts..Feb. 11, '10	John R. Hauser	Landon C. Flournoy, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of. Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of..Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University ,N. D.
Norwich University.....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ....Feb. 9, '12	W. F. Parsons	A. J. Ferlic, 718 N. Main Street Ada, Ohio.
Ohio State University...Dec. 20, '02	E. S. Gunn	T. D. Robb, 124 West 10th Ave., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col......Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	A. W. Walter	C. H. Whitwell, University of Oklahoma, Norman, Okla.
Oregon Agr. Col......Mar. 24, '08	J. A. Hooper	L. Happold, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02		
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams	W. R. Townsend, Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terra Haute, Ind.
Rhode Island State Col..Mar. 14, '13		
Stanford Univ......Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ......Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker, Throop Dormitory, Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	Baxter McIntosh	J. A. Carr, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	W. S. Rodman	J. K. Peebles, University, Va.
Wash., State Col. of.....Dec. 13, '07	S. Stites	E. Tollefson, State Coll. of Wash., Pullman, Wash.
Washington Univ......Feb. 5, '04		R. W. Mac Donald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	L. P. Kongsted	L. M. Lubcke, University of Washington, Seattle, Wash.
West Virginia Univ......Nov. 13, '14	O. P. Joliffe	D. F Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	B. Luther	N. L. Towle, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	B. P. O'Brian	G. P. Nevitt, 249 Park Street, New Haven, Conn.

Total 59

Digitized by Google

Digitized by Google

American Institute of Electrical Engineers

ESTABLISHED 1884

PROCEEDINGS

Vol. XXXVI DECEMBER, 1917 Number 12

INSTITUTE MEETING IN NEW YORK, DECEMBER 14, 1917

The 335th meeting of the American Institute of Electrical Engineers will be held in the Engineering Societies Building, 33 West 39th Street, New York, December 14, 1917, at 8:15 p.m.

Two papers will be presented at this meeting: *Magnetic Flux Distribution in Annular Steel Laminae*, by Dr. A. E. Kennelly and P. E. Alger of Massachusetts Institute of Technology; and *Phenomena Accompanying Transmission with Some Types of Star Transformer Connections—II*, by L. N. Robinson of Leland Stanford Jr. University. The latter paper is an amplification of Mr. Robinson's former paper presented at the Panama-Pacific Convention of the A.I.E.E., published in the TRANSACTIONS, Vol. XXXIV, 1915, page 2183.

Both papers are published in this issue of the PROCEEDINGS and reprints will be distributed at the meeting.

Non-members of the Institute who are interested in these subjects are cordially invited to attend and take part in the meeting.

ANNUAL MEETING OF THE A. S. M. E.

The annual meeting of the A. S. M. E. will be held in New York December 4 to 7, 1917 at Society Headquarters, 29 West 39th St. The meeting will be addressed at the opening session at 8:30 p. m. on Tuesday evening, December 4, by Hon. William H. Taft on the occasion of conferring Honorary Membership upon Major-General George W. Goethals.

On Wednesday, December 5, there will be an all-day session with addresses on problems relating to the war, such as agriculture, special education in wartime, transportation, merchant marine, aircraft, etc. While there will be the usual technical papers, there will also be certain other sessions dealing with war problems. One of these will discuss inspection of munitions, and other new developments in management resulting from war conditions, such as the employment of women in the manufacture of munitions and training crippled soldiers to become self-supporting.

There are to be two public hearings by committees, one on Power Test Codes of the Society preliminary to their revision. These relate to standard methods for testing prime movers and auxiliary apparatus. The other is a meeting of the Gage Committee established to assist in bringing about uniformity in gages used in establishing sizes and tolerances in the manufacture of the various products required by the Government for war purposes.

Of the social features, there will be the usual Smoker on Wednesday evening, December 5, with a talk by Mr. John R. Freeman, Past-President of the Society, on his recent trip to the Orient. On Thursday evening, December 6, there will be a lecture by Dr. John A.

Digitized by Google

Brashear, Past-President, on the "Science of the Beautiful in Commonplace Things."

The meeting will close on Friday, December 7.

MEETING OF THE INSTITUTE OF RADIO ENGINEERS

The next meeting of the Institute of Radio Engineers will be held on the evening of Wednesday, December 5th, at 8:15 p.m., on the sixteenth floor of the Engineering Societies Building, 33 West 39th St., New York., N. Y.

A paper by Dr. Frederick H. Millener of the Union Pacific Railroad, on "Radio Telephony" will be presented. Dr. Millener has carried out exhaustive researches on radio telephony to and from moving trains and will report the results in an interesting paper.

Institute members and their friends are cordially invited to attend.

FUTURE SECTION MEETINGS

Cleveland.—December 17, 1917. Subject: The Gasoline-Electric Automobile.

Lynn.—December 12, 1917. Subject: Motor Night.

Philadelphia.—December 10, 1917. Subject: Electricity and Conduit Construction. Speaker: H. C. Blackwell. Joint meeting with Engineers Club.

Pittsburgh.—December 8, 1917. Annual Banquet.

St. Louis.—December 20, 1917. Election of officers.

RECEPTION TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Invitations have been issued by the American Institute of Mining Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, and the United Engineering Society, to a general convocation of the four societies and the American Society of Civil Engineers, to which ladies are invited, on Friday evening, December 7, at 8:30 p.m., in the Engineering Societies Auditorium, 33 West 39th Street, New York.

The meeting is for the purpose of welcoming the American Society of Civil Engineers into the fraternity of Founder Societies and into the occupancy of the enlarged Engineering Societies Building.

Appropriate ceremomies will signalize the association of the societies for the first time under one roof, and the augmented solidarity of the engineering profession which that association promotes.

SCOPE OF FUTURE A.I.E.E. MEETINGS TO BE EXTENDED.

As announced in the November PROCEEDINGS, the Board of Directors, on the recommendation of the Meetings and Papers Committee, authorized a regular Institute meeting to be held during the coming winter in Cleveland. Arrangements are accordingly being made to hold the regular March meeting of the Institute in Cleveland under the combined auspices of the Cleveland, Detroit, Toledo, Toronto, and Pittsburgh Sections, all of which will cooperate in the preparation of the program and securing the discussion for this meeting.

Owing to the number of requests for regular Institute meetings by different Sections which have recently been received, the Meetings and Papers Commitee at its last meeting gave further consideration to the question of meetings for the current season, and in order to give several of the Sections an opportunity to participate in regular meetings, two so-called Inter-Sectional meetings were planned in which nearly simultaneous sessions will be held in two or more cities to consider the same paper.

Digitized by Google

In accordance with this plan the 336th meeting of the Institute in January will consist in the presentation of the same paper in Chicago, New York and Boston on different evenings with sufficient intervening time to give the author an opportunity to present his paper at the different places. A similar meeting, at which one paper will be presented at both Pittsburgh and New York, will be held in April.

The meeting at each of the cities taking part will be considered as part of the regular meeting, and the discussions at each place will form part of the regular published discussion in the TRANSACTIONS.

NOMINATIONS FOR INSTITUTE OFFICERS FOR 1918-19

As provided in Section 20 of the Institute by-laws, candidates may now be proposed for nomination for the offices to be filled at the next annual election in May, 1918, by the petition or by the separate endorsement in writing, of not less than fifty members. The petitions or separate endorsements must be in the hands of the Secretary not later than January 25, 1918. For the convenience of members, a form of petition has been prepared by the Secretary, and copies of it may be obtained upon application to Institute headquarters. Endorsements may, however, be made by letter if the form is not available. A member is not limited in the number of candidates he may endorse in this manner.

The officers to be elected are: a President and Treasurer, for the term of one year each, six Vice-Presidents for the term of one year each, and three Managers for the term of four years each.

The Constitution provides that "the President, Vice-Presidents and Managers shall not be eligible for immediate reelection to the same office. A Vice-President shall not be eligible for immediate election to the office of Manager."

For the information of members, the full text of Section 20 of the by-laws, governing the proposal of candidates for nomination, is printed below:

SEC. 20. In addition to the names of incumbents of office, the Secretary shall publish on the "form showing offices to be filled at the ensuing annual election in May" provided for in Article VI of the Constitution, the names, as candidates for nomination, of such members of the INSTITUTE as have been proposed for nomination for a particular office by the petition or by the separate endorsement of not less than fifty members, received by the Secretary of the INSTITUTE in writing by January 25 of each year.

The names of such candidates for nomination shall be grouped alphabetically under the name of the office for which each is proposed, and this by-law shall be reprinted prominently in the December and January issue of each year's PROCEEDINGS, and shall be reproduced on the form above referred to.

THE ENGINEERING SOCIETIES CLUB OF HAWAII.

The Engineering Societies Club of Hawaii has been established with headquarters at Honolulu, Hawaii. The officers are as follows: E. Kopke, President; E. C. Webster, Vice-President; E. F. Cykler, Secretary-Treasurer, 24 Pantheon Bldg.

This Club is an amalgamation of the A. S. C. E., the A. S. M. E., the A. I. M. E., the A. I. E. E., the American Society of Naval Engineers, the American Railway Engineering Association and the American Society for Testing Materials. A member of any one of these organizations being eligible to become a member of the Club.

The main purpose of this Club is for the entertainment of visitors from the various national organizations while in Honolulu and the Hawaiian Islands. Any member proposing to visit the Islands should make it a point to announce himself to the Secretary of the Engineering Societies Club of Hawaii so that he may be properly taken care of and that the various members may get into communication with him.

Digitized by Google

A. I. E. E. HONOR ROLL

Members of the American Institute of Electrical Engineers in Army and Navy service with the United States and her Allies.

This list includes only those members who are in the armed forces and who have responded to the War Service card sent to the membership on Sept. 15, 1917.

Members in Army and Navy service who are not listed are requested to communicate with Institute headquarters.

ABADIE, EUGENE H.
Major, U.S.R., Cantonment Division Headquarters.
ACHARD, FRANCIS H.
First Lieutenant, E. O. R. C.
ALDRICH, LOUIS C.
Radio Operator, U. S. S. Salem.
ALTLAND, COMER P.
Radio Operator, U. S. Army Transport Service.
AMES, AZEL
Major, New York Coast Artillery.
ANDERSON, EARL G.
Second Lieutenant, E. O. R. C., 302nd Engineers.
ANDERSON, PIERSON A.
Second Lieutenant, E. O. R. C., 301st Engineers.
ARNOLD, BION J.
Major, E. O. R. C.
ARNOLD, HAROLD D.
Captain, S. O. R. C.
R NOLD, HARRY S.
Captain, E. O. R. C.
ASHLEY, EDWARD E.
First Lieutenant, Aviation Section, Signal Corps.
AVERBACH, J. E.
First Lieutenant, Signal Corps.
AVERY, F. B.
Second Lieutenant, 314th Engineers.
BAER, C. A.
Captain, E. O. R. C.
BAKER, LOUIS A.
Sergeant, 319th Infantry.
BAKER, PAUL W.
Second Lieutenant, E. O. R. C., 314th Engineers.
BALDWIN, BERT L.
Major, E. O. R. C. (unassigned).
BARKER, HARRY
Captain, E. O. R. C.
BARNERT, MEYER
First Lieutenant, E. O. R. C., (unassigned).

KEY TO ABBREVIATIONS.

E. O. R. C.—Engineer Officers' Reserve Corps.
S. O. R. C.—Signal Officers' Reserve Corps.
C. A. O. R. C.—Coast Artillery Officers' Reserve Corps.
O. O. R. C.—Ordnance Officers' Reserve Corps.
U. S. R.—Unites States Reserve.
N. R. F.—Naval Reserve Force.

BARTON, PHILIP P,
Major, E. O. R. C.
BATES, F. R.
Corporal, 3rd Regiment, State Guard, Washington.
BEAR, S. LEE
Officers' Training Camp.
BEARY, D. B.
Lieutenant, U. S. Navy.
BEASLEY, T. E.
Second Lieutenant, E. O. R. C., (unassigned).
BEAVER, GEORGE L.
Second Lieutenant, E. O. R. C.
BECK, VERNON S.
Captain, E. O. R. C.
BEHRENS, EDWARD L.
Captain, U. S. Army.
BELCHER, W. A.
New Jersey Coast Artillery Reserve.
BEMAN, R. H.
Second Lieutenant, E. O. R. C.
BENEDICT, E. G.
First Lieutenant, 301st Engineers.
BENNETT, A. C.
First Lieutenant, E. O. R. C., (unassigned).
BERKELEY, L. R.
First Lieutenant, E. O. R. C., 107th Engineers.
BERSSENBRUGGE, B.
310th Engineers.
BESSESEN, BEN. B.
First Lieutenant, E. O. R. C., 316th Engineers.
BETTS, EUGENE
Major, Q. M., O. R. C.
BETTS, PHILANDER.
Major, E. O. R. C.
BEVERIDGE, WM. B.
First Lieutenant, S. O. R. C.
BILLINGS, A. W. K.
Lieutenant, senior grade, U. S. N. R. F.
BILLINGSLEY, F. N.
National Army.
BISHOP, REMSEN
Aviation Section, U. S. Expeditionary Force.
BLAIR, SHIRAS A.
First Lieutenant, Aviation Section, S. O. R. C.
BLAKE, EDWIN T.
Captain, E. O. R. C., (unassigned).
BLAKESLEE, D. W.
First Lieutenant, E. O. R. C.
BOGGS, CLARENCE
First Lieutenant, Eng. Corps.

Digitized by Google

BOHNERT, ARTHUR M.
First Lieutenant, 115th Engineers.
BOND, F. M.
Captain, Inspector of Ordnance.
BOWES, LAWRENCE C.,
332nd Field Artillery.
BOYD, RICHARD L.
Captain, 325th Infantry.
BRADLEY, C. R.
Aviation Section, Signal Corps.
BRANTLY, E. C.
First Lieutenant, E. O. R. C., U. S Expeditionary Force.
BREED, GEORGE
Lieutenant, U. S. Navy.
BRIGHTBILL, FLOYD G.
Second Lieutenant, C. A. O. R. C.
BRILL, G. M.
Major, O. R. C., (unassigned).
BROCKWAY, R. M.
Officers' Training Camp.
BROOKS, HENRY N.
Captain, 308th Engineers.
BROOME, F. H.
Electrician, U. S. Army Hospital No. 6, U. S. Expeditionary Force.
BROWN, GLENN O.
117th Field Battalion, Signal Troops, 42nd Army Division.
BROWN, N. F.
Second Lieutenant, E. O. R. C.
BROWN, ROSCOE D.
Captain, Infantry Division Headquarters, Camp Meade.
BRUMHALL, JOHN H.
Second Lieutenant, Officers' Training Camp.
BRUNDAGE, DARIUS C.
Second Lieutenant, E. O. R. C.
BRYANT, R. B.
First Lieutenant, S. O. R. C.
BUCHANAN, J. L.
Engineers' Training Camp.
BURNHAM, WM. A.
Captain, E. O. R. C.
BURNS, THOMAS S.
Second Lieutenant, Officers' Training Camp.
BUSH, GEORGE P.
First Lieutenant, S. O. R. C.
BUTLER, ALBERT S.
Second Lieutenant, U. S. R.
BYRNE, WALTER S.
First Lieutenant, O. O. R. C.
BYRNS, R. A.
First Lieutenant, 107th Infantry.
CABOT, F. ELLIOT
First Lieutenant, First Motor Corps, Mass. State Guard.
CALDWELL, E. W.
Captain, Medical Officers' Reserve Corps.
CARPENTER, DAVID E.
319th Infantry.
CARTY, JOHN J.
Colonel, Signal Corps.
CASE, CHARLES D.
Coast Artillery Corps.
CASSIDY, PERRY R.
Captain, C. A. O. R. C.
CHAFFE, J. B. JR.
First Lieutenant, O. O. R. C.
CHANDLER, C. DE F.
Colonel, Signal Corps, Balloon Div.
CHAPMAN, F. W.
First Lieutenant, U. S. R., U. S. Expeditionary Force.
CHAPPELL, WM. H.
Chief Engineer, U. S. S. Garner.
CHATFIELD, C. E.
First Lieutenant, E. O. R. C.
CHILD, R. S.
First Lieutenant, Ordnance Dept.
CHILDS, R. B.
Captain, Infantry, N. A.
CLARK, F. J.
First Lieutenant, S. O. R. C.
CLARK, R. P.
Officers' Training Camp.
CLARKE, E. C.
Training Camp, Aviation Section, S. O. R. C.
CLARKE, FRANK J.
First Lieutenant, S. O. R. C.
CLARKE, V. A.
First Lieutenant, 308th Engineers.
CLEMENT, M. F.
Chief Electrician, U. S. N. R. F.
CLOKEY, A. A.
Captain, S. O. R. C.
COHO, H. B.
Captain, Q. M., O. R. C.
COLE, HORACE L.
Radio Electrician, U. S. N. R. F.
CONDON, E. J. JR.
Second Lieutenant, E. O. R. C.
COOK, JOHN
First Lieutenant, O. O. R. C.
COOKE, MERRITT T., JR.
E. O. R. C., U. S. Expeditionary Force.
COUSINS, V. D.
Captain, C. A. O. R. C.
CRAFT, E. B.
Captain, S. O. R. C.
CRAMER, L. B.
Captain, E. O. R. C.
CRAWFORD, D. K.
Signal Reserve Corps, (unassigned).
CREECY, C. EATON
Lieutenant, S. O. R. C.
CRIM, L. P.
First Lieutenant, Ordnance Dept.
CROCKER, JAMES R.
Captain, E. O. R. C., 106th Pioneers.
CROSBY, L. S.
Ensign, U. S. N. R. F.
CUNTZ, JOHN H.
Captain, S. O. R. C.
CURETON, JAMES G.
Field Artillery Training Camp.
CURTIS, AUSTEN M.
First Lieutenant, S. O. R. C.
DALE, H. L.
First Lieutenant, E. O. R. C.

Digitized by Google

DAMON, JOHN C.
Captain, E. O. R. C.

DAVIDSON, WARD F.
First Lieutenant, E. O. R. C., 308th Engineers.

DAVIS, JOHN W.
First Lieutenant, Aviation Section, S. O. R. C.

DAVISON, V. A.
Electrician, U. S. N. R. F.

DE WYRALL, OSCAR E.
102nd Engineers.

DEXTER, HARRIS E.
Lieutenant, 30th Engineers (Gas and Flame).

DICKIESON, A. L.
Railway Troops, Canadian Forces, France.

DIMMER, L. G.
Royal Engineers.

DIXON, JAMES
Lieutenant, (junior grade), U. S. N. R. F., (unassigned).

DONALDSON, J. M.
Captain, 16th King's Royal Rifles.

DORSEY, OTIS B.
301st Machine Gun Battalion, 76th Div.

DUFFY, FRANK J.
Major, 103rd Engineers.

DUNLAP, H. B.
Officers' Training Camp.

DYOTT, G. M.
Squadron Commander, Royal Naval Air Service, France.

EATON, BERNARD L.
Captain, O. O. R. C.

EDDY, LLOYD C.
Second Lieutenant, E. O. R. C.

EHRLICH, L. B.
Officers' Training Camp.

EINSTEIN, R. H.
National Army.

ELLISON, LOUIS H.
Captain, E. O. R. C.

ELSSERGIAN, R.
First Lieutenant, E. O. R. C.

EMERSON, A. T.
Master Electrician, Coast Artillery.

EVANS, LOUIS M.
Captain, S. O. R. C.

FAIRBANKS, FRANK B.
Signal Corps.

FAIRLEY, G. E. A.
Captain, E. O. R. C.

FALKENAU, ROBERT M.
Captain, Q. M., U. S. R., U. S. Expeditionary Force.

FERNOW, B. E. JR.,
First Lieutenant, E. O. R. C.

FIELD, CROSBY
First Lieutenant, O. O. R. C.

FINNEY, J. H.
Major, E. O. R. C., 105th Engineers.

FISHER, E. H.
305th Ammunition Train.

FITZ, E. S.
66th Aero Squadron.

FITZGERALD, GEO. G.
First Lieutenant, E. O. R. C.

FLETCHER, JOHN W.
Second Lieutenant, E. O. R. C.

FOLEY, J. W. B.
Radio Electrician (first class), U. S. N. R. F.

FRANKENBERRY, T. H.
Aviation Section, S. O. R. C.

FREEMAN, J. W.
First Lieutenant, Engineers.

FRIDAY, E. C.
National Army.

FRYE, JASON L.
National Army.

FULLERTON, D. P.
Major, S. O. R. C.

FURLONG, W. R.
U. S. S. Nevada.

FURNESS, DOUGLAS L.
Elec. Gunner, U. S. N. R. F.

GAILLARD, D. ST. P.
First Lieutenant, O. O. R. C.

GAMBRILL, W. N.
Second Lieutenant, E. O. R. C.

GARDNER, F. Q. C.
Captain, N. Y. Coast Artillery.

GARRETT, J. H.
Ensign, U. S. S. Frederick.

GASH, FRANK T.
Second Lieutenant, Engineer Corps.

GAUSS, W. F.
Captain, S. O. R. C., U. S. Expeditionary Force.

GERBER, LIPMAN S.
Second Lieutenant, Ordnance Dept.

GFORER, A. H.
First Lieutenant, O. O. R. C.

GIBBONY, ALVIN P.
15th Engineers, U. S. Expeditionary Force.

GILCHRIST, T. ERNEST,
10th Battery, Canadian Field Artillery, France.

GOETZENBERGER, R. L.
First Lieutenant, U. S. R., U. S. Expeditionary Force.

GOLDSMITH, ELSWORTH H.
Master Signal Electrician, Signal Reserve Corps.

GOLDTHWAITE, G. E.
School of Military Aeronautics.

GOODWIN, A. JR.
Lieutenant, U. S. N. R. F.

GORMAN, H. B. L.
Captain, E. O. R. C.

GORMAN, L. J.
First Lieutenant, Signal Corps.

GOTSHALL, WM. C.
Major, Engineer Corps.

GRAY, G. FRANCIS
Captain, O. O. R. C., (unassigned).

GREEN, C. W.
Captain, C. A. O. R. C.

GREENLEAF, MYNDRET C.
335th Regiment.

Digitized by Google

GRISWOLD, A. H.
Major, 8th Telegraph Battalion, Signal Reserve Corps.
GROWDON, JAMES P.
Captain, E. O. R. C., 4th Engineers.
GUISE, HIRAM B.
Major, O. O. R. C., (unassigned).
GUSTAFSON, R. V.
108th Engineers.
HAGUE, ALFRED E.
Second Lieutenant, N. Y. Coast Artillery.
HALL, E. C.
Officers' Training Camp.
HAMLEN, H. H.
Lieutenant, U. S. N. R. F.
HARDENBERGH, J. R.
Chief Electrician, U. S. S. Kentucky.
HARE, K. R.
First Lieutenant, O. O. R. C.
HARISBERGER, JOHN
Captain, E. O. R. C.
HARRIES, GEORGE H.
Brigadier General, 59th Depot Brigade.
HART, ROY H.
Sergeant, Signal Corps, (unassigned).
HART, R. PHILIP
Second Lieutenant, E. O. R. C.
HAUSMANN. V. F.
331st Infantry.
HAWK, LESLIE L.
First Lieutenant, O. O. R. C.
HAYES, DANIEL W.
First Lieutenant, S. O. R. C.
HAYES, HAMMOND V.
Lieutenant, (Industrial), N. R. F.
HAYNES, A. R.
Captain, E. O. R. C., 316th Engineers.
HEINZE, CARL A.
Captain, E. O. R. C.,
HERDT, L. A.
Lieutenant, McGill, Training Camp, Canada.
HEUER, REINHOLD H.
Sergeant, 128th Infantry.
HILL, F. W. L.
Second Lieutenant, 302nd Engineers.
HILL, M. W.
Captain, E. O. R. C.
HIRSCH, GUSTAV
Major, S. O. R. C.
HODGES, W. L.
Major, N. Y. Guard.
HOHN, EMIL
First Lieutenant, E. O. R. C.
HOLBROOK, FREDERICK M.
Corporal, 2nd Regiment, Reserve Militia, Illinois.
HOLCOMB, T. W.
First Lieutenant, E. O. R. C.
HOLLAND, MAURICE
Signal Corps, Officers' Training Camp.
HOLLAND, W. E.
359th Infantry.
HOLMES, Albert
Lieutenant, 1st Engineers, U. S. Expeditionary Force.
HOLTZ, F. C.
314th Field Signal Battalion.
HORNER, L. S.
Major, Signal Corps.
HORNING, A. W.
Second Lieutenant, 324th Regiment, Heavy Field Artillery.
HORST, A. C.
Radio, Co., Signal Corps.
HORTON, W. H. JR.
Lieutenant, Ordnance Dept.
HOWE, H. L. JR.
Lieutenant, U. S. S. Wisconsin.
HOWE, WM. M.
Second Lieutenant, E. O. R. C.
HULING, JOHN E.
Corporal (instrument), 3rd Field Artillery.
HUNT, WALTER S.
Second Lieutenant, Royal Engineers.
IMES, OLIVER S.
First Lieutenant, S. O. R. C.
JACKSON, JOHN P.
Major, E. O. R. C.
JEFFE, EPHRAIM F.
First Lieutenant, S. O. R. C.
JEFFERS, G. L.
Officers' Training Camp.
JENKS, H. LEE
Private, Depot Battalion, National Guard N. Y.
JERSEY, CHESTER C.
Line Officer, U. S. N.
JEWETT, F. B.
Major, S. O. R. C.
JOHNS, HYLAND R.
Sergeant, Coast Artillery.
JOHNSON, CHARLES F.
Captain, 319th Infantry.
JOHNSON, OTTO H.
Second Lieutenant, E. O. R. C.
JOHNSON, WILLARD C.
Officers' Training Camp.
JONES, C. A.
Lieutenant Commander, U. S. N.
JONES, GEO. H.
Second Lieutenant, 2nd Regiment, Illinois Reserve Militia.
JONES, KENNETH B.
Second Lieutenant, E. O. R. C. 104th Engineers.
JONES, REID
Captain, E. O. R. C.
JONES, R. E.
Mechanical Transport, Canadian Expeditionary Force, France.
JONES, REGINALD L.
Captain, S. O. R. C.
JOSEPHS, LYMAN C. JR.
First Lieutenant, E. O. R. C.
JOYCE, J. B. JR.
2nd Regiment, Field Artillery, National Guard, N. J.
JUNKERSFELD, P.
Major, E. O. R. C.
KANE, JOHN J.
Officers' Training Camp.

Digitized by Google

KATTE, EDWIN B.
Major, E. O. R. C. (unassigned).
KAUMHEIMER, EDWIN A.
Second Lieutenant, 310th Engineer Train, 85th Div.
KEELER, FRANK S.
22nd Engineers, N. Y.
KEELER, N. B.
Captain, E. O. R. C.
KEENAN, EDWARD T.
Captain, Engineer Corps.
KEENE, A. D.
Second Lieutenant, Engineer Corps.
KEHL, R. J.
First Lieutenant, O. O. R. C.
KELLY, JOSEPH T. JR.
Captain, E. O. R. C., 305th Engineers.
KENNEDY, ALEXANDER, JR.
First Lieutenant, Engineer Corps, U. S. Expeditionary Force.
KENNEDY, OWEN W.
Second Lieutenant, E. O. R. C.
KENNEDY, SCOTT J.
First Lieutenant, S. O. R. C.
KENNEDY, VERNE C.
First Lieutenant, 4th South Dakota Infantry.
KEPLINGER, WM. L.
Captain, E. O. R. C.
KERRIGAN, ARTHUR J.
Chief Yeoman, U. S. N. R. F.
KEYES, EDWIN F.
Sergeant (first class), Signal Corps.
KIERSTEAD, FRIEND H.
Second Lieutenant, E. O. R. C., 301st Engineers.
KILGOUR, HAMILTON
Division Officer, Royal Engineers.
KIRCHNER, HENRY P.
First Lieutenant, O. O. R. C.
KISTLER, ROY E.
Second Lieutenant, E. O. R. C., 301st Engineers.
KIVLIN, ALFRED P.
Second Lieutenant, 301st Engineers.
KNIGHT, EARL W.
Lieutenant, 331st Infantry, N. A.
*KNOWLTON, A. E.
E. O. R. C.
KORNFELD, FREDERICK H.
First Lieutenant, E. O. R. C. (unassigned).
KREY, B. H.
First Lieutenant, Aviation Section, Signal Corps, U. S. Expeditionary Force.
KREIGSMANN, A. E.
Captain, E. O. R. C., 308th Engineers.
KUTNER, S. D.
Second Lieutenant, E. O. R. C.
KYLE, ELMER L.
First Lieutenant, O. O. R. C. (unassigned).
LACOMBE, CHARLES F.
Captain, 25th Engineers.
LAING, G. S.
Officers' Training Camp.
LANCASTER, WM. C.
Captain, E. O. R. C. (unassigned).
*Commission Pending.

LATZER, FREDERICK
Corporal, 302nd Engineers.
LAWSON, F. I.
Signal Corps, N. A.
LAWSON, JOEL S.
First Class Petty Officer, U. S. N. R. F.
LEAVITT, ARTHUR R.
Sergeant, 76th Aero Squadron, Signal Corps.
LEE, CARL
First Lieutenant, E. O. R. C.
LEE, CLAUDIUS
Captain, O. O. R. C.
LEGIER, EDWARD W.
First Lieutenant, 310th Engineers.
LEILICH, FRANK T.
First Lieutenant, U. S. R.
LEMP, H. J.
Second Lieutenant, 16th Penn. Infantry.
LIBBEY, MILES A.
Lieutenant Commander, U. S. N.
LICHTENBURG, CHESTER
Second Lieutenant, E. O. R. C.
LITTLE, J. H.
Officers' Training Camp.
LLOYD, AUSTIN M.
First Lieutenant, Ft. Leavenworth.
LONG, CARL C.
Aviation Service.
LOVELL, A. H.
Major, 310th Engineers.
LUEDTKE, FRANK P.
Second Lieutenant, E. O. R. C. (unassigned).
LUFKIN, FRED R.
Electrician, Mass. General Hospital, Base Hospital Unit No. 6.
LUSTER, ERIC W.
Second Lieutenant, E. O. R. C., 2nd Engineers.
LYNETT, JAMES D.
Electrician (first class), U. S. S. Kentucky.
LYON, R. R.
Captain, Coast Artillery.
LYSTER, T. L. B.
Major, Signal Corps, France.
MACOMBER, ALEXANDER
Captain, E. O. R. C.
MacGREGOR, JAMES J.
Canadian Engineers Training Camp.
MAC TAVISH, HERBERT J.
Lieutenant, Royal Field Artillery, France.
MAGEE, JOHN W.
Second Lieutenant, E. O. R. C.
MAHAN, J. H.
Aviation Section, Signal Corps.
MAILHOUSE, ROBERT J.
U. S. N. R. F.
MALBY, SETH G.
First Lieutenant, O. R. C.
MANSON, G. K.
Major, S. O. R. C.
MAPES, MILTON C.
First Lieutenant, 301st Engineers.
MARKHAM, CARL W.
Captain, E. O. R. C.
MARTIN, KINGSLEY G.
Captain, Motor Truck Co. 57.

Digitized by Google

MARTINDALE, E. H.
Captain, E. O. R. C.
MAXWELL, F. R.
U. S. N. R. F.
MAXWELL, J. M. S.
Captain, Royal Engineers.
MAY, RICHARD B.
First Lieutenant, E. O. R. C., 308th Engineers.
MAYER, EDWIN C.
Captain, C. A. O. R. C.
McCLURE, D. C.
First Lieutenant, 314th Engineers.
McDOUGAL, CHARLES A.
Training Camp.
McGEACHIN, W. R.
Captain, E. O. R. C.
McGRATH, M. K.
Major, S. O. R. C., U. S. Expeditionary Force.
McIVER, G. W. JR.
Captain, E. O. R. C.
McKEE, GROSVENOR S.
First Lieutenant, E. O. R. C.
McKEE, MYRON
First Lieutenant, E. O. R. C.
McKELVEY, CLINTON F.
12th Telegraph Battalion.
McLAY, ANGUS D.
First Lieutenant, S. O. R. C.
McLELLAN, WILLIAM.
Lieutenant Colonel, British Forces. (Assigned to Admiralty).
McLEMAN, J. C. E.
Aviation Section, Signal Corps.
MERSHON, RALPH D.
Major, E. O. R. C.
METZ, E. C.
Lieutenant, U. S. N.
MILLAR, EDWARD A. JR.
First Lieutenant, Ordnance Dept.
MILLER, FREDERICK
First Lieutenant, E. O. R. C.
MILLER, J. EDGAR
Captain, E. O. R. C., U. S. Expeditionary Force.
MILLER, LORIMER D.
Captain, E. O. R. C.
MOORE, CHARLES J.
Second Lieutenant, E. O. R. C.
MORGAN, JOHN D.
First Lieutenant, E. O. R. C.
MORELY, E. L.
Naval Coast Reserve.
MORROW, RUSH B.
Captain, E. O. R. C.
MULOCK, REDFORD H.
Squadron Commander, Royal Naval Air Service.
MURPHY, J. J.
Second Lieutenant, E. O. R. C.
NEWHALL, WM. B.
Captain, E. O. R. C.
NEXSEN, R. H.
First Lieutenant, U. S. S. Kentucky.
NICKEL, L. W.
Electrician, U. S. N. R. F.
NIMS, LESLIE W.
First Lieutenant, 316th Engineers.
NOLTE, ROBERT W.
First Lieutenant, E. O. R. C., 7th Engineers.
NORMAN, C. L.
26th Engineers.
OAKES, MALCOLM C.
344th Field Artillery, N. A.
OLSON, RAYMOND F.
First Lieutenant, 116th Engineers.
ORBISON, THOMAS E.
First Lieutenant, E. O. R. C.
O'REILLY, THOMAS W.
Captain, Medical Officers' Reserve Corps.
OWENS, ROBERT B.
Captain, S. O. R. C.
PANTON, H. D.
Lieutenant, Ft. Ceswell, N. C.
PARKHURST, A. F.
Lieutenant, U. S. N. R. F.
PASTORIZA, HUGH
First Lieutenant, O. O. R. C.
PEASE, MAURICE N.
Captain, 301st Engineers.
PEIRCE, A. E.
Captain, E. O. R. C.
PENNEY, F. H.
Officers' Training Camp.
PERRIN, L. M.
First Lieutenant, Signal Corps.
PERRY, EDGAR R.
Second Lieutenant, E. O. R. C.
PETERSON, ALFRED J. A.
Camp American University.
PETERSON, C. A.
Captain, E. O. R. C.
PHILBRICK, J. S.
Gunner, U. S. N. R. F.
PHILIP, HERBERT A.
First Lieutenant, 302nd Engineers.
POLLOCK, JOHN D.
First Lieutenant, S. O. R. C.
POLSTER, M. A.
National Army.
POPE, C. J.
First Lieutenant, Motor Ordnance Section.
POST, F. B.
Sergeant, Coast Artillery.
PRESCOTT, R. D.
Captain, S. O. R. C.
PRICE, MILTON N.
Ensign, U. S. N. R. F., U. S. S. Sylvia.
PRINCE, D. C.
First Lieutenant, Ordnance Dept.
PRIOR, ALLEN A.
First Lieutenant, C. A. O. R. C.
RAAB, HARRY F.
Second Lieutenant, E. O. R. C.
RAINES, HERBERT
143rd Field Artillery.
RAMSAY, J. ARTHUR
First Lieutenant, Engineers(unassigned).
RAMSAY, JOSEPH W.
First Lieutenant, Aviation Section, S.O.R.C.

Digitized by Google

RANSOPHER, SILAS M.
Captain, 117th Field Battalion, Signal Troops, 42nd Division.
REDDIE, WM. W.
Camp Lee, Va.
REED, H. P.
Lieutenant, N. R. F.
REHFIELD, GROVER G.
Captain, Ft. Leavenworth, Kansas.
REYNOLDS, RALPH W.
Second Lieutenant, E. O. R. C.
RICHARDS, KEENE
Captain, S. O. R. C.
ROBERTS, C. W.
First Lieutenant, O. O. R. C.
ROBERTS, HENRY G.
Officers' Training Camp.
ROBERTS, SPENCER
First Lieutenant, 304th Engineers.
ROBERTS, W. S.
Officers' Training Camp.
ROBISON, CHARLES D.
Captain, E. O. R. C., 306th Engineers.
ROCKWELL, ROBERT L.
Corporal, Washington State Guard.
ROGERS, ASA L.
Lieutenant, 301st Engineers.
ROGERS, CLARENCE B.
Private, 201st Aero Squadron.
ROOP, J. CLAWSON
Captain, 17th Engineers, U. S. Expeditionary, Force.
RORTY, M. C.
Major, O. O. R. C.
ROSE, C. E.
Captain, E. O. R. C.
ROSE, W. H.
Major, General Engineer Depot.
ROSENBLATT, ARTHUR M.
First Lieutenant, E. O. R. C.
ROWELL, L. D.
Captain, E. O. R. C.
RUGG, HAROLD H.
Sergeant, 4th Infantry, South Dakota National Guard.
RUSSEL, EDGAR
Colonel, Chief Signal Officer, General Pershing's Staff, France.
RUST, E. P.
Chief Engineer, U. S. S. Sialia.
SAMPLE, RALPH M.
Master Engineer, 102nd Engineers.
SANDS, WM. H.
Second Lieutenant, 315th Field Artillery.
SCHALLER, W. F.
Lieutenant, O. O. R. C.
SCHANTZ, L. C.
Officers' Training Camp.
SCHLUTER, W. H. F.
Ensign, U. S. S. Leviathan.
SCHOEL, W. A.
Captain, E. O. R. C.
SCHOEPF, T. H.
Captain, 15th Engineers, U. S. Expeditionary Force.
SCHULTZ, G. E.
N. J. State Militia.
SCHWARTING, H. F.
Corporal, N. A.
SEALEY, P. THWAITES
Captain, E. O. R. C. (unassigned).
SHALLCROSS, W. M.
Captain, E. O. R. C., 26th Engineers.
SHAND, ERROL B.
Sergeant, 10th Halifax SiegeBattery, Canada.
SHAW, CARROLL H.
Captain, E. O. R. C.
SHEPARD, E. M.
First Lieutenant, Officers' Training Camp.
SHEPPARD, HARRY S.
Captain, S. O. R. C.
SHRIEVE, HERBERT E.
Major, S. O. R. C., France.
SIGMAN, JOS.
Electrician (2nd class), Naval Base Hospital, League Island Pa.
SILVA, A. D.
Officers' Training Camp.
SIMPSON, ALSTON R.
Lieutenant, U. S. S. DeKalb.
SIMPSON, FREDERICK G.
Lieutenant Commander, U. S. N. R. F.
SKEHAN, E. A.
Lieutenant, U. S. N. R. F.
SLADE, ARTHUR J.
Captain, Aviation Section S. O. R. C.
SMITH, ROBERT W.
Second Lieutenant, E. O. R. C., 106th Engineers.
SNOW, WILBUR R.
Electrician (first class), U. S. N. R. F.
SOMERS, R. H.
Major, Ordnance Dept.
SPEIRS, C. W.
Captain, 5th Surrey Volunteer Regiment.
SPENCER, C. G.
First Lieutenant, Aviation Section, S. O. R. C.
STANTON, RAYMOND L.
First Lieutenant, E. O. R. C.
STANWICH, C. A.
Second Lieutenant, E. O. R. C.
STARR, ARTHUR B., JR.
First Lieutenant, 154th Field Artillery.
STEIN, SAMUEL
National Army.
STEINBACH, EDW. S.
301st Infantry.
STEINER, LEO E.,
Signal Reserve Corps.
STEVENOT, J. E. H.
Captain, Signal Corps, Philippine National Guard.
STEWARD, W. A.
Master Signal Electrician, Signal Reserve Corps.
STONE, DONALD D.
First Lieutenant, Ordnance Dept.,
STORZ, J. F.
Officers' Training Camp.

Digitized by Google

STOTTLER, MALCOLM W.
Corporal, 319th Infantry.
STRATEMEYER, EDWIN A.
Officers' Training Camp.
STUDE, A. J.
14th Engineers, U. S. Expeditionary Force.
SULTZER, MORTON
First Lieutenant, S. O. R. C.
SWAN, GEORGE L.
Lieutenant, Depot Brigade, Camp Devens, Mass.
SWARTZ, TASSO W.
Lieutenant, 53rd Infantry.
TATUM, L. L.
Lieutenant Commander, U. S. N. R. F.
TAUSSIG, WM. S.
Captain, E. O. R. C., 114th Engineers.
TAYLOR, WILLIAM T.
Captain, Royal Flying Corps, France.
TENNEY, ROBERT B., JR.,
First Lieutenant, S. O. R. C.
THOMAS, HERBERT C.
First Lieutenant, E. O. R. C., France.
THOMPSON, E. G.
Provisional Ensign, U. S. N. R. F.
THOMPSON, JOHN F.
Colonel, Ordnance, War Dept.
THOMPSON, W. R.
Captain, 109th Engineers.
THOMSON, W. H., JR.
Captain, E. O. R. C.
THORNE, HOWARD O.
105th Engineers.
THORNTON, GEO. C.
Captain, 106th Engineers.
TILLSON, PERCY E.
Lieutenant, U. S. N. R. F.
TINSLEY, JOHN F.
Major, O. O. R. C. (unassigned).
TOUCHE, ARTHUR S.
First Lieutenant, E. O. R. C.
TOWLE, THOMAS D.
Second Lieutenant, E. O. R. C., 310th Engineers.
TOWNSEND, CHARLES P.
Officers' Training Camp.
TOWNSLEY, F. P.
Captain, E. O. R. C., 311th Engineers.
TREAT, ROBERT B.
Major, O. O. R. C.
TRINKLE, R. J.
Officers' Training Camp.
TRIPIER, HENRI
Captain, Artillery, Paris.
TRUST, H. G.
British Expeditionary Force, France.
TURNOCK, H. C.
First Lieutenant, Coast Artillery, U. S. Expeditionary Force.
TWOGOOD, RALPH S.
Captain, E. O. R. C. (unassigned).
VAWTER, JAMES H.
Captain, E. O. R. C. (unassigned).
VICKERY, W.
Captain, U. S. R., Motor Supply Train.
VON SCHRENK, ARNOLD
First Lieutenant, Aviation Section, S. O. R. C.
WAGNER, C. F.
Captain, E. O. R. C.
WAITE, LESLIE O.
Second Lieutenant, E. O. R. C., 302nd Engineers.
WALDMANN, C. A.
Captain, Ordnance Dept.
WALKEM, GEO. A.
Captain, Royal Engineers, Egyptian Expeditionary Force.
WARD, BUTLER E.
Second Lieutenant, E. O. R. C., 303rd Engineers.
WARNER, OSCAR C.
Captain, Coast Artillery.
WARNER, RUSSEL A.
First Lieutenant, E. O. R. C.
WATT, GEORGE Y.
Chief Electrician, U. S. N. R. F.
WEBB, L. W.
Master Electrician, U. S. Navy.
WEBSTER, JAMES C.
First Lieutenant, E. O. R. C.
WEISS, CHARLES G. A.
Chief Petty Officer, Electrical, U.S. N. R. F.
*WELKER, JAS. A.
First Lieutenant, E. O. R. C.
WELLER, F. M.
First Lieutenant, O. O. R. C.
WELLS, A. E.
Major, 121st Infantry.
*WHITE, HARRY L.
First Lieutenant, O. O. R. C.
WHITE, LLOYAL R.
Officers' Training Camp.
WHITEHEAD, J. B.
Major, E. O. R. C.
WHITNEY, ERLE F.
Captain, E. O. R. C. (unassigned).
WILLIAMS, EDMUND F.
First Lieutenant, E. O. R. C.
WILLIAMS, SAMUEL S.
Aviation Section, Signal Reserve Corps.
WILSON, EVERITT W.
Captain, E. O. R. C.
WILSON, HENRY C.
Major, Coast Artillery.
WILSON, JAMES R.
Second Lieutenant, E. O. R. C., 304th Engineers.
WILSON, PERCY J.
Captain, 304th Engineers.
WILSON, RICHARD M.
Second Lieutenant, E. O. R. C.
WIMAN, L. E.
Officers' Training Camp.
WINKLEY, S. F.
Lieutenant, Royal Naval Volunteer Reserve.
WINSHURST, H. E.
E. O. R. C.

*Commission pending.

Digitized by Google

WOLF, H. C.
First Lieutenant, E. O. R. C.
WOODHULL, L. R.
Captain, E. O. R. C., 304th Engineers.
WOOLFSON, MONROE G.
305th Infantry.
WORTHINGTON, E. H.
Officers' Training Camp
WULSIN, LUCIEN
First Lieutenant, Engineer Corps, France.
WURTS, THOMAS C.
First Lieutenant, E. O. R. C.
YUNDT, GEO. J.
Major, S. O. R. C.
ZORING, H. H.
Captain, Ordnance Dept.

MEMBERSHIP SERVICE CLASSIFICATION

Under date of November 1 the following letter was mailed to each member of the Institute, together with the classification form referred to therein:

November 1, 1917

To the Membership of the Institute

GENTLEMEN:

Various branches of the Army, Navy, and other governmental departments as well as many industrial establishments, are calling upon the Institute for assistance in obtaining men of specified technical qualifications. To respond promptly and effectively it is necessary that detailed information regarding the many Institute members who are available and anxious to serve, shall be on file at Institute headquarters.

Accordingly the Directors have authorized the Secretary to request each member to fill out and return the enclosed classification form which has been prepared by the cooperation of several engineering societies with the object of covering all branches of engineering, and of providing for uniformity in classification, in the hope that ultimately the records thus obtained by different societies may be combined in a single index in a central bureau.

Your prompt cooperation, even though you have already filled out similar blanks for other organizations and whether you are available for service or not, is requested. Particular attention should be devoted to the record of your technical training and experience on page 2 and the index schedule which follows.

Although the immediate need of obtaining and indexing this information is to enable the Institute to render greater service to the Government, the intention is to maintain a permanent file of such data, revised from year to year; this is needed in connection with the regular work of the Institute, and will probably prove of increasing value after peace has been declared, in providing for the readjustment in the industries, with a view to the utilization of the services of the membership to the best advantage of the individual engineer and of the nation.

Very truly yours,
F. L. HUTCHINSON,
Secretary

About two thousand members have already responded by filling out and returning the form to Institute headquarters, and the information thus obtained is now being classified in card-index form at Institute headquarters under the direction of a committee on classification consisting of Messrs. A. S. McAllister, Chairman, W. A. Del Mar and William McClellan. These records will be of great value, not only to meet the demands upon the Institute from the Army, Navy, and other branches of the Goverment, in connection with the present war situtation, but will also be available for many purposes in connection with the regular activities of the Institute.

Members who have not yet returned the classification form particularly those who are available at the present time for service, either military or civilian are urged to give the matter their early attention.

A. I. E. E. DIRECTORS' MEETING NEW YORK, NOVEMBER 9, 1917

The regular monthly meeting of the Board of Directors was held at Institute headquarters, New York, on Friday, November 9, 1917, at 3:30 p. m.

There were present: Vice-Presidents, B. A. Behrend, Boston, Mass., L. T. Robinson, Schenectady, N. Y., Frederick Bedell, Ithaca, N. Y., A. S. McAllister, New York; Managers, John B. Taylor, Schenectady, N. Y., Harold Pender, Philadelphia, Pa., C. E. Skinner and Wilfred Sykes, Pittsburgh, Pa., N. A. Carle, Newark, N. J., William A. Del Mar, New York; Treasurer, George

Digitized by Google

A. Hamilton, Elizabeth, N. J., and Secretary, F. L. Hutchinson, New York.

In the absence of President Rice, Senior Vice-President Behrend presided.

The action of the Finance Committee in approving monthly bills amounting to $8806.58 was ratified.

The Meetings and Papers Committee reported having held a meeting earlier in the afternoon, at which a tentative schedule of meetings for the balance of the administrative year was decided upon as follows.

December 14, 1917, regular Institute meeting in New York; January 11, 1918, regular Institute meeting in New York, and Institute meetings in Boston and Chicago, under the auspices of the local Sections, exact dates to be decided upon later; the same technical papers to be presented at all three meetings; February 14, 15, 16, 1918, Mid-winter Convention, New York; March 8, 1918, regular monthly Institute meeting in Cleveland, under the auspices of the Cleveland, Detroit, Toledo, Toronto and Pittsburgh Sections. (There will be no meeting in New York in March) April 12, 1918, regular Institute meeting in New York, and Institute meeting in Pittsburgh, exact date of which is to be decided later, the same paper to be presented at both meetings; May 17, 1918, Annual business meeting in New York; June, 1918, Annual Convention week beginning Monday, June 24, 1918, the location to be decided later.

The report of the Board of Examiners of its meeting held on October 30, 1917, was presented and the actions taken at that meeting were approved. Upon the recommendation of the Board of Examiners the following action was taken upon pending application: 96 students were ordered enrolled, 21 applicants were elected to the grade of Associate, 1 applicant was reinstated to the grade of Associate, 3 applicants were elected to the grade of Member, and 4 applicants were transferred to the grade of Member. The names of these applicants will be found elsewhere in this issue.

The attention of the Board of Directors having been called to the organization of the Professional Classes War Relief of America, the following resolution was adopted:

RESOLVED, that the Board of Directors of the American Institute of Electrical Engineers hereby expresses its sympathy with the movement which has resulted in the organization of the Professional Classes War Relief of America, and heartily endorses the aims and purposes of this relief organization, which has been created by the cooperation of members of the various professions.

A letter was read, dated Rome, October 4, 1917, from Signor Guglielmo Marconi, expressing his appreciation of the honor conferred upon him by the Board of Directors in electing him an Honorary Member of the Institute.

A considerable amount of other business was transacted, reference to which will be found under appropriate headings in this and future issues of the PROCEEDINGS.

A. I. E. E. MEETING IN NEW YORK NOVEMBER 9, 1917

The 334th meeting of the Institute was held at Institute headquarters, 33 West 39th Street, New York, November 9, 1917. In the absence of the President, Mr. E. W. Rice. Jr., the Senior Vice-President, Mr. B. A. Behrend, called the meeting to order at 8:20p.m. The attendance was about 175.

Mr. Behrend after expressing his regret at the absence of President Rice made a few remarks relative to the paper of the evening and then turned the meeting over to Prof. Frederick Bedell, Chairman of the Electrophysics Committee.

Prof. Bedell introduced Mr. Chester W. Rice who presented in abstract his paper entitled "*An Experimental Method of Obtaining the Solution of Electrostatic Problems with Notes on High-Voltage Bushing Design*". The discussion which followed was participated in by the following men: Major Ralph D. Mershon, Past-President C. O. Mailloux, Mr. John B. Taylor, Prof. A. M. Gray, Mr. Charles L. Fortescue, Mr. E. DeWitt Eby,

Digitized by Google

Mr. F. W. Peek, Jr., Mr. M. E. Tressler, Mr. H. O. Stephens, Mr. S. W. Farnsworth, Mr. D. P. Orcutt, Mr. Selby Haar and Mr. B. A. Behrend. Mr. C. W. Rice then made his closure and the meeting adjourned.

GOVERNMENT SERVICE.

Civil Engineering Corps of U. S. Naval Reserve Force: An examination will be held to select an eligibility list for candidates for enrolment as civil engineers in the U. S. Naval Reserve Force. Those now in the U. S. Naval Reserve Force and civilians are eligible.

All papers and other information required of candidates must reach the Reserve Examining Board, Bureau of Yards and Docks, Navy Department, Washington, D. C., by noon of December 31, 1917.

Upon the decision of a candidate that he is desirous of entering and can fulfill the requirements of a position in the Corps of Civil Engineers, U. S. Naval Reserve Force, he should fill in the blank spaces of a notification blank and mail it to the Examining Board. This should be done immediately, as it will be to the candidate's interest to get this blank to the Board as soon as possible.

The candidate must be an American citizen and must be an engineer in the active practise of the profession of civil electrical or mechanical engineering, or some business directly connected therewith.

To be eligible for the rank of ensign, a candidate must be not less than 24 years of age and in active professional practise not less than two years.

To be eligible for the rank of lieutenant (junior grade) an applicant must be not less than 27 years of age and in active professional practise not less than five years.

To be eligible for the rank of lieutenant a candidate must be not less than 30 years of age and in active professional practice not less than seven years and must have had responsible charge of work as principal or assistant for at least three years.

Notification blanks to be filled out by the applicant may be obtained upon application to A. L. Parsons, Acting Chief of Bureau of Yards and Docks Navy Department, Washington, D. C.

Radio Service U. S. A. (Non-flying): Electrical men are needed for radio work for the aviation section of the Signal Corps. Men with previous radio experience are considered desirable candidates for this service, but radio experience is not absolutely necessary and men who have had experience in telegraphy can quickly pick up the essentials and by practise become of equal value. In fact any man who has had electrical experience will be able to grasp the fundamentals quickly and in a short time become proficient in the work required.

A training school has been established for intensive education of radio operators and mechanicians at Camp Kelly, Texas, and the course of training will last from six to eight weeks under most capable instructors the Signal Corps can provide.

In addition to the elementary electrical knowledge which is necessary, the course will include the following subjects: Radio power circuits, primary circuits, secondary circuits, condensers, oscillations, radiated currents, ether, received waves, receiving circuits, detectors, wave meters, instruments.

The last part of the course will be devoted to practical work and the operators will be required to take the apparatus out on the field and communicate with airplanes under actual flying conditions. Repair men during the same time will work with the apparatus which is to be used on the planes and will learn how to install, repair and care for this apparatus.

Applicants will be enlisted as privates and will remain as such until they have been assigned to their proper places in a squadron.

If an applicant for enlistment has had a college education or its equivalent, he

Digitized by Google

may consider himself eligible for a non-flying commission in the Aviation Section of the Signal Corps.

Application forms for enlistment in this branch of the service may be obtained from the Secretary of the Institute.

Air Service U. S. A. (Non-flying): There is room on the ground behind the lines abroad for capable skilled American workers to become Non-Commissioned Officers. Squadrons are being formed and picked men (skilled workers) are being enrolled from many trades. These men will be given special training, according to their vocations, in work required in the Air Service. They will get actual practise work on airplane motors, trucks, airdrome construction, and everything that will be done on the other side. As soon as qualified, assignments will be made with rank, according to ability (corporal or sergeant). Pay is clear gain as all living expenses are borne by the government. Applicants must be physically sound, white, and from 18 to 40 years of age. For application blank and particulars apply to Volunteer Bureau, 119 D Street, N. E., Washington, D. C.

PAST SECTION MEETINGS

Boston. October 16, 1917, Engineers Club. Lecture by Dr. A. E. Kennelly on "Laboratory Tests on Long Alternating-Current Lines." Attendance 75.

November 13, 1917, Massachusetts Institute of Technology. Address by Mr. F. W. Peek, Jr., on "The Phenomena of Lightning." Attendance 205.

Chicago.—October 22, 1917, W. S. E. Rooms. Lieut. Col. L. D. Wildman, Chief of Signal Corps, Central Department, gave an address on "The Engineering Problems of the Signal Corps." Motion pictures entitled "Who Leads the National Army" were shown. Attendance 210.

Cleveland.—October 22, 1917, Hotel Statler. Address by Mr. C. N. Rakestraw on the activities of the Section for the coming year. Paper: "Engineering Education in the Army Colleges" by H. B. Dates. Attendance 42.

Denver.—October 20, 1917, Denver Athletic Club. Address by Professor R. D. George on "Oil Possibilities in the Rocky Mountain Region." Attendance 30.

Detroit-AnnArbor.—October 12, 1917, Detroit Engineering Society Hall. Paper: "Transmission and Distribution Systems" by D. W. Roper. Attendance 90.

November 9, 1917, Detroit Board of Commerce Building. Illustrated address by Mr. A. M. Dudley on "Speed-Torque Characteristics of Industrial Motors."

Ithaca.—October 19, 1917, Cornell University. Papers: (1) "Reduction Gear for Ship Propulsion" by Alexander Gray; (2) "Experience in the Design of a Large Power Plant" by H. W. Brown; (3) "Mercury Vapor and Tungar Rectifiers" by R. F. Chambarlain. Attendance 45.

Los Angeles.—October 23, 1917. Meeting and dinner of the Joint Technical Societies of Los Angeles, at which Dr. Ira N. Hollis, member of Advisory Committee of National Council of Defense, gave an address on "Problems relating to the War." Dr. Hale of Mt. Wilson Observatory also addressed the meeting on "International Awakening in Scientific and Industrial Research." Attendance 241.

Minnesota.—October 18, 1917, Hotel Radisson. Welcome Dinner in honor of John R. Allen, the new Dean of the College of Engineering and Architecture of University of Minnesota. Attendance 105.

Panama.—October 21, 1917, Ancon, C. Z. Illustrated lectures as follows: (1) "Marine Animals" by H. W. Nightinggale; (2) "Isthmian Entomology" by L. H. Dunn. Attendance 52.

Philadelphia.—November 12, 1917. Engineers Club. Paper: "A Public Utility's Method of Standardization for their Electrical Instruments" by W. F. Johnson. Paper was illustrated by lantern slides. Attendance 88.

Digitized by Google

Pittsburgh.—November 13, 1917, Arcade Building Paper. "Arc Welding" by A. M. Candy. Attendance 75.

Pittsfield.—October 25, 1917, Hotel Wendell. Short address by Mr. G. Faccioli on "Qualifications for a Successful Engineer." Lecture by Prof. W. S. Franklin on "Wave Motion." Attendance 200.

November 8, 1917, Hotel Wendell. Illustrated lecture by Mr. D. B. Rushmore on "The Economic Basis of Industrial Activity." Attendance 135.

Portland.—November 6, 1917, Multomah Hotel. Address by Captain Palmer of U. S. A. Eng. Corps, entitled "First Campaign of the War Ending with German Advance on English Channel." Attendance 50.

Rochester.—October 26, 1917, Rochester Engineering Society. Paper: "Some Prominent Factors in the Design and Operation of Modern Common Battery Switchboards" by R. H. Manson. Attendance 24.

San Francisco.—October 25, 1917, Palace Hotel. Address by Dr. Ira N. Hollis on "The Moral Influence of Engineering and Efficiency." Joint meeting of local branches of the national engineering societies.

Schenectady.—October 23, 1917, Edison Club Hall. Illustrated address by Captain G. P. Capart of the French General Staff on "The Engineer at the Battle of Verdun." Attendance 765.

November 13, 1917, Edison Club Hall. Address by Dr. Clayton H. Sharp on "Terminology and Measurements of Illuminating Engineering." Mr. G. H. Stickney, President of Illuminating Engineering Society, introduced the speaker. Joint meeting with local branch of Illuminating Engineering Society. Attendance 175.

Spokane.—October 19, 1917, Spokane Hotel. Address by Dr. E. O. Holland on "The Engineers' Responsibility as a Citizen." Attendance 46.

St. Louis.—September 26, 1917, Engineers' Club Rooms. Paper: "What Electricity Is" by Terrell Croft. Attendance 83.

October 24, 1917, Engineers' Club. Address by Prof. A. C. Lanier on "The Training of Engineers." Attendance 50.

Toledo.—October 24, 1917, Toledo Commerce Club. Paper: "The Underground System of Toledo" by M. E. Grah.

Toronto.—October 19, 1917, Engineers' Club. Paper: "Transformer Design as Influenced by the Quality of Steel" by Frank T. Wyman. Attendance 50.

October 26, 1917. Tour of the recent engineering developments in Toronto Harbor. Attendance 35.

Washington.—November 13, 1917, Cosmos Club Hall. Illustrated address by Mr. W. R. McCann on "The Panama Canal and Its Electrification." Address by Mr. F. A. Brown on "The Design for the Locks of the Panama Canal." Attendance 142.

PAST BRANCH MEETINGS

University of Arkansas.—October 29, 1917, Engineering Hall. Organization meeting. Addresses by Mr. Robison and Prof. Wadleigh. Attendance 12.

November 12, 1917, Engineering Hall. Papers: (1) "Magneto Ignition vs. Battery Ignition;" (2) "The Electric Furnace in the Steel Industry." Address by Prof. Halperin on "Mathematics." Attendance 10.

Armour Institute.—October 18, 1917. Y. M. C. A. Rooms. Illustrated addresses as follows: (1) "Distribution of Central Station Energy through Substations" by E. W. Grover; (2) "Electron Theory" by W. C. Bauer. Attendance 35.

November 7. 1917, Physics Lecture Room. Addresses as follows: (1) "Types, Uses and Advantages of Relays" by E. H. Freeman; (2) "Relays in Transmission Lines" by D. W. Roper. Attendance 44.

Brooklyn Polytechnic Institute.—November 2, 1917, Mailloux Library. Illustrated lecture on "Commercial Meter Testing" by F. E. Canavaciol. Attendance 22.

Digitized by Google

University of California.—October 10, 1917. Paper: "Power Line Construction" by F. H. Vernon. Attendance 19.

Carnegie Institute of Technology.—October 17, 1917. Election of officers as follows: chairman, W. F. Eames; vice-chairman, R. C. Barron; student secretary, F. K. Ball; permanent secretary, B. C. Dennison; treasurer, W. R. Fuller; executive committee, Messrs. E. M. Pugh, L. J. Murphy and Geo. N. Flocus. Addresses on "Technical Experiences during the Past Summer" by Messrs. W. F. Eames, F. K. Ball and E. M. Pugh. Attendance 27.

Clarkson College.—November 7, 1917. Paper: "The Brayton Cycle Engine" by A. R. Powers. Attendance 8.

Colorado State Agricultural College.—October 9, 1917, Electrical Building. Demonstration meeting. Attendance 55.

October 22, 1917, Electrical Building. Address by Prof. L. S. Foltz on "Rail Bonding." Attendance 10.

Kansas State Agricultural College.—November 8, 1917, Denison Hall. Papers: (1) "Characteristic Curves of Shunt, Series and Compound Generators, also the Hysteresis Loop; (2) "Electric Ship Propulsion;" (3) "The X-Ray;" (4) "Electrical Service on the Chicago, Milwaukee and St. Paul R. R." Address by Prof. C. E. Reid on "The Draft Situation." Attendance 44.

University of Kansas.—October 9, 1917. Address by Mr. W. H. Bettz giving his experience as a wireless telegraph operator on the U. S. S. Philadelphia. Address by Prof. Geo. C. Shaad on "The A. I. E. E. and Its Relation to the Student." Attendance 68.

October 24, 1917, Marvin Hall. Election of officers as follows: chairman, Clarence Lynn; vice-chairman, Charles L. Shughart; secretary-treasurer, Robt. W. Warner. Attendance 39.

November 7, Marvin Hall. Addresses as follows: (1) "Theory of the A-C. Watthour Meter" by H. J. Gish; (2) "Design of a Portable A-C. Test Set" C. L. Shughart; (3) "Present Day Tendencies in Watthour Meters" by A. R. Farnsworth. Attendance 28.

Lafayette College.—October 20, 1917, Pardee Hall. Papers: (1) "The Corona Voltmeter;" (2) "Methods of Making Power Investigations." Attendance 16.

Lehigh University.—October 25, 1917, Physics Building. Papers: (1) "Experiences at General Electric Works during Summer Vacation" by G. R. Lawall; (2) "Theory of Electrons and Some Practical Applications of the Vacuum Tube" by S. S. Seyfert. Attendance 77.

Massachusetts Institute of Technology.—October 22, 1917, Lecture by Captain E. C. Canfield, U. S. A. on "The Construction of Camp Devens." Attendance 83.

November 13, 1917, Smith Hall. Illustrated address by Mr. F. W. Peek, Jr., on "The Phenomena of Lightning." Attendance 282.

University of Missouri.—October 15, 1917, Engineering Building. Election of Emery Spracklin as vice-chairman. Addresses as follows: (1) "The Institute, Its Scope " by H. B. Stone; (2) "The Student Branch" by E. Groesbech. Attendance 23.

November 5, 1917, Engineering Building. Papers: (1) "Relation of Electrical Engineering to the Allied Field" by A. C. Lanier; (2) "Electricity and Its Various Applications" by M. S. Weinbach. Attendance 26.

University of Nebraska.—November 7, 1917, Electrical Engineering Building. Illustrated address by Prof. E. E. Brackett on "The Development and Present Status of Farm Lighting Plants." Attendance 28.

North Carolina College of Agricultural and Mechanical Arts.—November 5, 1917. Illustrated lecture by Mr. F. N. Bell on Power Plant of the Southern Aluminum Company." Attendance 10.

University of North Dakota.—October 29, 1917. Subject: Summer Experiences. Speakers: Messrs. J. F. Stevens, E. L. Marsh and R. A. Wehe.

Ohio Northern University.—October 24, 1917. Addresses as follows: (1) "Power Plant of the American Gas and Electric Co. at Windsor, W. Va." by

Digitized by Google

Chester Sterling; (2) "Industrial Developments of China" by E. A. Lee.

November 7, 1917. Election of officers as follows: Chairman, W. F. Parsons; vice-chairman, J. E. Summers; secretary, A. J. Ferlic; treasurer, A. Alholm; executive committee, J. E. Hawe, W. E. Ward, R. E. Long, L. D. Beatty. Addresses as follows: (1) "Electrification of the C. M. & St. Paul R. R." by J. E. Hawe; (2) "The Overland Survey of the Toledo Railway and Light Company" by G. R. Brace.

Ohio State University.—October 19, 1917, Physics Hall. Address by Mr. S. G. McMeen on "The Life and Works of Thomas A. Edison." Attendance 65.

November 2, 1917, Robinson Laboratory. Address by Mr. S. E. Shilling on "The Advancement of Illumination." Attendance 37.

November 16, 1917, Robinson Laboratory. Address by Mr. J. C. Lincoln on "Arc Welding." Attendance 41.

Oregon Agricultural College.—November 1, 1917. Address by Professor R. H. Dearborn. Attendance 35.

Pennsylvania State College.—November 1, 1917, Engineering Club Room. Discussion on "Power Plants" by Messrs. Laughrey, Wycoff and Taylor. Mr. Markle gave an address on "Forced Cooling of the Connelsville Plant." Attendance 51.

November 14, 1917. Address by Mr. Markle on "Characteristics of Tungsten Lamps." Attendance 40.

Rensselaer Polytechnic Institute.—November 13, 1917, Sage Laboratory. Election of officers as follows: chairman, Wynant J. Williams; secretary Leroy C. Witt; executive committee, Norman S. Galvin, James A. Simons, Lewis T. Spruks, Charles G. Humphrey, Earl D. Rhodes, and Philip R. Schilling. Attendance 53.

Syracuse University.—November 1, 1917. Paper: "Central Stations and Their Commercial Problems" by M. O. Dell Plain. Attendance 29.

November 8, 1917 Paper: "The Hydraulic Power Company of Niagara Falls" by R. S. Wells. Attendance 13.

Agricultural and Mechanical College of Texas.—October 17, 1917. Papers: (1) "Vacation Experiences" by W. D. Sexaur; (2) "Phenomena of the Short Circuit" by F. A. Cooper. Attendance 30.

November 14, 1917. Papers: (1) "Contractors and Their Problems" by A. R. McLean; (2) "Electricity in the Present Day War" by J. B. Miller. Attendance 22.

Virginia Polytechnic Institute.—October 24, 1917, Science Hall. Illustrated lecture by Mr. B. S. Parrish on "Edison and the Development of Electric Lighting." Attendance 32.

University of Virginia.—October 29, 1917. Election of officers as follows: chairman, Charles Henderson; secretary, James Arthur Evans; Address by Prof. W. S. Rodman on the main features of Mr. Ryan's paper "Illumination of the Panama Exposition." Attendance 25.

University of Washington.—October 23, 1917. Paper: "The Demand for Technically Trained Men" by C. E. Magnusson. Attendance 19.

November 6, 1917. Paper: "The Electrical Equipment of the Port of Seattle" by C. P. Gordon. Attendance 20.

State College of Washington.—October 26, 1917. Address by Professor M. K. Akers on "Advice and Success." Attendance 23.

November 9, 1917. Paper: "Modern Ship Construction on the Pacific Coast" by A. C. Abell. Attendance 21.

Worcester Polytechnic Institute.—October 31, 1917, Electrical Engineering Hall. Papers: (1) "The Worcester Polytechnic Institute Test Car" by E. K. Bloss; (2) "High-Tension Insulator Testing" by H. W. Thompson; (3) "The Three-Phase Power Relay" by L. W. Bond; (4) "Impressions of the Westinghouse Electric and Manufacturing Co." by D. B. Webster. Attendance 40.

Yale University.—October 19, 1917. Paper: "Electric Drive for Battleships" by Wilfred Sykes. Attendance 165.

Digitized by Google

ASSOCIATES ELECTED NOVEMBER 9, 1917

ANDREAE, FRITZ VOLKMAR, Head Electrician, Southern Manganese Corp.; res., 1206 Quintard Ave., Anniston, Ala.

*BENKESSER, GRANT E., Engineering Dept., Carborundum Co.; res., 806 Cedar Ave., Niagara Falls, N. Y.

BIBIGHAUS, ALEXANDER JOSEPH, Electrical and Mechanical Designer, Engineering Dept., Bethlehem Steel Co., S. Bethlehem, Pa.

BLITMAN, CHARLES HOWARD, City Engineer and Manager, Glasgow, Montana.

CLARKE, JOHN LEONARD, Engineer, Bell Telephone Co. of Canada, Notre Dame St.; res., 2300 Park Ave., Montreal, Quebec.

DRIGGS, LORENZO J., Superintendent, Penn Public Service Co.; res., 352 S. 6th St., Indiana, Pa.

ELSOM, C. HAWTHORNE, Member of Firm, West Virginia Engineering Co.; res., 1513 Virginia St., Charleston, W. Va.

*ENGER, THORBJORN K., Transformer Engineering Dept., General Electric Co.; res., 1546 North St., Pittsfield, Mass.

FLEMING, ELLIOTT, Electrical Engineer, Union Steamship Co., Port Chalmers, N. Z.

GIRDLESTONE, CHARLES FREDERICK, 17 Seabank Road, Egremont, Cheshire, England.

GRUBBS, CHARLES, District Foreman Coast Valleys Gas & Electric Co.; res., 334 Capital St., Salinas, Cal.

*HAYASHI, YAGENDA, Electrical Engineer, Hitachi Engineering Works, Sukegawa, Ibaragi-ken, Japan.

KELLAR, HERBERT AUSTIN, Hydroelectric Station Operator, Colorado Power Co., Glenwood Springs; res., 1021 Lincoln Pl., Boulder, Colo.

MILLER, WILLIAM HOWARD, General Electric Co., Fort Wayne Works; res., 1118 Cass St., Fort Wayne, Ind.

*OAKES, CHARLES ERNEST, Assistant Electrical Engineer, Bureau of Standards, Washington, D. C.

PERLESZ, HUGO, Production Manager, Electro Dynamic Co.; res., La Tourette Hotel, Bayonne, N. J.

PRITCHARD, AMOS DURBEN, Western Electric Co., Hawthorne Station; res., 1515 W. Monroe St., Chicago, Ill.

SYRON, THOMAS A., Electrical Contractor, 196 Scott St., Wilkes-Barre, Pa.

*TOYOMURA, CHUSHIRO, Electrical Engineer, Hitachi Engineering Works, Sukegawa, Ibaragi-Ken, Japan.

*WATSON, JAMES LEWIS, General Electric Co., Schenectady, N. Y.; res., 500 E. 23rd St., Vancouver, Wash.

WOLFINGER, LOUIS FREDERICK, Head of Mechanical and Electrical Dept., Consolidated Engineers, 803 Baker-Detwiler Bldg., Los Angeles, Cal.

* Former enrolled students.

Total 21.

ASSOCIATE REELECTED NOVEMBER 9, 1917

MILLER, ANDREW OTTERSON, Engineer, J. G. White Corp.; res., 338 W. 86th St., New York, N. Y.

MEMBERS ELECTED NOVEMBER 9, 1917

CLOTHIER, HENRY WILLIAM, Manager, A. Reyrolle & Co. Ltd., Hebburn-on-Tyne, England.

SPENGLER, WARREN D., Electrical Engineer, Firestone Tire & Rubber Co., Akron; res., Hudson, Ohio.

VAN DER BIJL, H. J., Research Physicist, Western Electric Co.; res., 509 West 121st St., New York, N. Y.

TRANSFERRED TO THE GRADE OF MEMBER, NOVEMBER 9, 1917

COOK, JAMES A., Assistant Chief of Laboratory, New York Edison Co., New York, N. Y.

FRANKLIN, RAYMOND E., Superintendent of Electrical Dept., Yukon Gold Co., Dawson, Y. T.

HEIDENREICH, ALLAN H., Electrical Engineer, Firestone Tire & Rubber Co., Akron, O.

SNYDER, FREDERICK T., President, Electric Furnace Corp., Chicago, Ill.

Digitized by Google

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its regular monthly meeting, held on October 30, 1917, recommended the following members of the Institute for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the Secretary.

To Grade of Fellow

McNICOL, DONALD, Assistant Electrical Engineer, Postal Telegraph Cable Co., New York, N. Y.

To Grade of Member

ALLING, SYDNEY, Engineer Electric Distribution, Rochester Railway & Light Co., Rochester, N. Y.

BEAVER, JACOB L., Distribution Dept., Philadelphia Electric Co., Philadelphia, Pa.

CADBY, JOHN N., Consulting Engineer, Madison, Wis.

CHASE, PHILIP H., Assistant Engineer, Public Service Electric Co., Newark, N. J.

HAZELTINE, LOUIS A., Acting Professor of Electrical Engineering, Stevens Institute of Technology, Hoboken, N. J.

SCHATTNER, ERNEST, Chairman, Electrical Apparatus Co. Ltd., Vauxhall Works, London, England.

WAUGH, LESTER R., Assistant Engineer, Chile Copper Co., Chuquicamata, Chile.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated the applicant has applied for admission as an Associate. If the applicant has applied for admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before December 31, 1917.

Allen, J., Norristown, Pa.
Arnold, B. H., Erie, Pa.
Arnold, J. L., (Member), New York, N. Y.
Bagley, G. D., Pittsburgh, Pa.
Becker, A. J., Rochester, N. Y.
Bird, C. W., Detroit, Mich.
Bonamy, L. J., Detroit, Mich.
Bovee, B. A., Milwaukee, Wis.
Brooks, H. W., (Member), Bay City, Mich.
Burch, W. S., (Member), Rochester, N. Y.
Busch, R. E., Erie, Pa.
Cannady, N. E., Raleigh, N. C.
Carter, E. L., Indianapolis, Ind.
Chace, C. R., Central Falls, R. I.
Chan, P. K., Cleveland, Ohio
Conant, F. N., Newburyport, Mass.
Cook, H. K., Norristown, Pa.
Curtis, L. H., Erie, Pa.
Digby, W. P., (Member), London, Eng.
Fear, L. G., Portland, Ore.
Fogerty, J. S., E. Pittsburgh, Pa.
Frost, C. A., Cleveland, Ohio
Ganser, H. H., (Member), Norristown, Pa.
Gellion, F. J., (Member), Macao, S. China
Gibbs, R. T., Boston, Mass.
Gaudy, R. J., (Member), Chicago, Ill.
Goodwin, W. C., E. Pittsburgh, Pa.
Guynes, W. M., Erie, Pa.
Hancock, E. A., Boston, Mass.
Hansen, N. J., New York, N. Y.
Harris, H. L., Rochester, N. Y.
Hart, J. M., Norristown, Pa.
Heiser, C. E., Reading, Pa.
Hennig, W. E., Milwaukee, Wis.
Hess, A. F., New York, N. Y.
Hildebrandt, H. A., Minneapolis, Minn.
Hill, S. S., Erie, Pa.
Isdale, J. S., Ottawa, Ont.
Jacobsen, F., (Fellow), Stavanger, Norway.
Kaiser, A. A., Philadelphia, Pa.
Kampf, W. E., Brooklyn, N. Y.
Kennedy, T. O., (Member), Denver. Colo.
Kephart, S. W., San Francisco, Cal.
Klein, H., New York, N. Y.
Kruse, S., New York, N. Y.
Leatham, W. T., Detroit, Mich.
Lee, P. M., Norristown, Pa.
Lesniewski, Witold, Petrograd, Russia

Digitized by Google

Lovell, C. M., Pittsburgh, Pa.
Marcott, A. H., Erie, Pa.
Markley, R. E., Norristown, Pa.
McClenathan, R. F., Erie, Pa.
Metzner, M. W., Erie, Pa.
Newell, L. B., Pittsfield, Mass.
Oehler, A. G., Westfield, N. J.
Oetinger, H. W., New York, N. Y.
Ostline, J. E., Aberdeen, S. Dakota
Oswalt, H. I., Salisbury, Md.
Peakes, G. L., Perth Amboy, N. J.
Pfaff, R. W., Norristown, Pa.
Polson, A. V., Seneca Falls, N. Y.
Porter, A. F., Detroit, Mich.
Rasmussen, W. C. O., Jersey City, N. J.
Reinke, E. A., Rochester, N. Y.
Riddle, R. B., Carney's Point, N. J.
Roe, R. C., Fairbury, Ill.
Ryder, R. B., (Member), Philadelphia, Pa.
Shannon, W. J., Waterbury, Conn.
Sibley, E. D., (Member), Reading, Pa.
Smith, A. P., Norristown, Pa.
Stafford, J. W., Lafayette, Ind.
Steinke, J. J., Erie, Pa.
Stevens, G. A., Buffalo, N. Y.
Stewart, R. B., Ithaca, N. Y.
Stoffert, H. A., (Member), Reading, Pa.
Strawn, C. M., Norristown, Pa.
Thompson, L. M., Wilmington, Del.
Trowbridge, D. F., Milwaukee, Wis.
Watterson, H. E., City Point, Va.
Willmarth, G. M., Boston, Mass.
Winte, H. F., Detroit, Mich.
Woodward, A. C., Baltimore, Md.
Wright, N. A., So. San Francisco, Cal.
Total 83.

STUDENTS ENROLLED NOVEMBER 9, 1917

9165 Yung, H. L., Yale Univ.
9166 Reichel, H. W., Yale Univ.
9167 Farrand, B. R., Yale Univ.
9168 Greer, G. B., Yale Univ.
9169 Clark, F. S., Yale Univ.
9170 Newell, H.H., Worcester Poly. Inst.
9171 Tavares, O., Ohio Northern Univ.
9172 Kolbe, H. J., Univ. of Ky.
9173 Scott, L. R., Penn. State Coll.
9174 Wearstler, F. W., Ohio Northern Univ.
9175 Bull, H. S., Lehigh Univ.
9176 Crago, H. R., Penn. State Coll.
9177 Moses, M.S., Ohio Northern Univ.
9178 Houran, W. L., Penn. State Coll.
9179 Lawton, O. T., Casino Tech. Night School
9180 Diniz, W., Ohio Northern Univ.
9181 Nogueira, M. de S., Ohio Northern Univ.
9182 Cominsky, J., Yale Univ.
9183 Moore, H. S., Yale Univ.
9184 Murphy, J. J., Yale Univ.
9185 O'Brien, P. C., Yale Univ.
9186 Pohja, H., Yale Univ.
9187 Seacord, K. P., Yale Univ.
9188 D. H. Sundel, Yale Univ.
9189 Summers, J.E., Ohio Northern Univ.
9190 Schleinkafer, G.N., Penn State Coll.
9191 Budd, J. S., Ga. School Tech.
9192 Allis, S. P., Cornell Univ.
9193 Gaertner, H. A., Cornell Univ.
9194 Everitt, W. L., Cornell Univ.
9195 Ku, C., Cornell Univ.
9196 Johnson, W. L., Jr., Cornell Univ.
9197 Silsbee, B. F., Univ. of Neb.
9198 Rice, H. F., Univ. of Colo.
9199 Schaefer, F. L., Cornell Univ.
9200 Garver, P. L., Cornell Univ.
9201 Shaeffer, G. D., Ohio Northern Univ.
9202 Webster, D. B., Worcester Poly. Inst.
9203 Memoli, J., Ala. Poly. Inst.
9204 Doughtie, C.E., Jr., Ala. Poly. Inst.
9205 West, W. B., Ala. Poly. Inst.
9206 Ard, J. C., Ala. Poly. Inst.
9207 Allen, W. W., Ala. Poly. Inst.
9208 Duggar, L. G., Ala. Poly. Inst.
9209 Guess, W. A., Ala. Poly. Inst.
9210 Withington, W., Ala. Poly. Inst.
9211 Huey, S. R., Ala. Poly. Inst.
9212 Carlovitz, G. H., Ala. Poly. Inst.
9213 Spencer, J. W., Ala. Poly. Inst.
9214 Matthes, L.H., A. & M. Coll. of Tex.
9215 Reisman, A.M., A. & M. Coll. of Tex.
9216 Weyland, A.H., A. & M. Coll. of Tex.
9217 Murrah, F.V., A. & M. Coll. of Tex.
9218 Sexaner, W.G., A. & M. Coll. of Tex
9219 Copeland, C.M., A. & M. Coll. of Tex.
9220 Priester, L.E., A. & M. Coll. of Tex.
9221 McLean, A.R., A. & M. Coll. of Tex.
9222 Hancock, P., A. & M. Coll. of Tex.
9223 Tighe, L. T., A. & M. Coll. of Tex.
9224 Miller, J. B., A. & M. Coll. of Tex.

Digitized by Google

9225 Rutherford, T. B., Worcester Poly. Inst.
9226 O'Neill, W. J., Worcester Poly. Inst.
9227 Peterson, P., Penn. State Coll.
9228 Lipscomb, T. G., A. & M. Coll. of Tex.
9229 Newbowers, F. J., S. D. State School of Mines
9230 Hallen, F. A., Yale Univ.
9231 Franklin, R. F., Syracuse Univ.
9232 Gordon, W. J., Syracuse Univ.
9233 Lowell, G. J., Syracuse Univ.
9234 Moore, L. N., Syracuse Univ.
9235 Givens, E. C., Yale Univ.
9236 Boothroyd, C. O., Syracuse Univ.
9237 Nickle, C. A., Penn. State Coll.
9238 Tobey, C. R., Cornell Univ.
9239 Nirenberg, B. R., Cornell Univ.
9240 Farrell, M. W., Cornell Univ.
9241 Roat, R. H., Cornell Univ.
9242 Hoyle, E. R., N. Y. Elec. Sch.
9243 Wainwright, S. F., Tufts Coll.
9244 Craig, J. A., Univ. of Illinois.
9245 Landa, M.I., A. & M. Coll. of Tex.
9246 Clayton, H.M., A. & M.Coll.of Tex.
9247 Allen, H. M., A. & M. Coll. of Tex.
9248 Bavcom, J.W., A. & M.Coll. of Tex.
9249 Cooper, F.A., A. & M. Coll. of Tex.
9250 Schoonover, M. E., Ohio No.Univ.
9251 Beatty, L. D., Ohio No. Univ.
9252 Rouk, H. D., Ohio No. Univ.
9253 Stone, H. B., Missouri State Univ.
9254 Spracklen, E. E., Missouri State Univ.
9255 Zaugg, F. R., Univ. of Washington
9256 Bloss, E. K., Worcester Poly.Inst.
9257 Brooke, H. L., Univ. of Minnesota
9258 Neal, P. L., A. & M. Coll. of Tex.
9259 Denny, W. M., A. & M. Coll. of Tex.
9260 Porter, J., Jr., A. & M. Coll. of Tex.

Total 96.

PERSONAL

C. G. Cox, District Manager of McIntosh & Seymour at St. Louis has transferred his office to San Francisco because of the greatly increasing field for marine Diesel oil engines on the Pacific coast.

OBITUARY

JOHN GILMARTIN, Superintendent of Meter Department of the Detroit Edison Co., died at his home in Detroit on November 12th from typhoid fever. Mr. Gilmartin was a pioneer in electric meter work. His early experience was gained in Toledo and from there he was called to Detroit, where he was put in charge of the Meter Department. He was a member of the N. E. L. A., and an associate of the A. I. E. E.

ACCESSIONS TO THE UNITED ENGINEERING SOCIETY LIBRARY

(From October 1 to November 1, 1917)

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statements made. These are taken either from the preface or the text of the book.

All the books listed may be consulted in the United Engineering Society Library.

AEROPLANE DESIGN.

By F. S. Barnwell and A SIMPLE EXPLANATION OF INHERENT STABILITY. By W. H. Sayers. N. Y., Robert M. McBride & Co., 1917. 102 pp., 28 illus., 7x5 in., cloth, $1.

Two papers previously published in the Aeroplane. In the first Mr. Barnwell attempts a *precis* of the general principles for the information of trained engineers without experience in airplane design. Mr. Sayers offers a non-mathematical explanation of the known principles by which inherent stability may be attained.

APPLIED ELECTROCHEMISTRY AND WELDING.

A Practical Treatise on Commercial Chemistry, the Electric Furnace, the Manufacture of Ozone and Nitrogen by High-Tension Discharges, and the Applications of Electric, Gas and Chemical Welding to Manufacturing and Repair Work. Part I—Applied Electrochemistry by Charles F. Burgess; Part 2—Welding by George W. Cravens. Chicago, American Technical Society, 1917.

Digitized by Google

83+132 pp., 186 illus., 8x6 in., cloth, $1.50.

A concise account of the principles involved in electrolysis, electrothermics and electrical discharges in gases, of the apparatus used commercially and of the products obtained. The section devoted to welding describes the methods of riveting, welding, soldering and cutting with electricity, gases and thermit.

A TREATISE ON THE ELEMENTS OF ELECTRICAL ENGINEERING.

A Text Book for Colleges and Technical Schools by William S. Franklin. Volume I Direct and Alternating Current Machines and Systems. N. Y., The Macmillan Company, 1917. 465 pp., 368 illus., 9x6 in., cloth, $4.50. (gift of the author)

Written to encourage a first course in electrical engineering covering both direct and alternating current machines and systems. The emphasis throughout is on the simple physics of the subject and on operating engineering. The book entitled Electric Lighting and Miscellaneous Applications of Electricity will henceforth be known as volume two of the present treatise.

CALCULATIONS USED IN CANE SUGAR FACTORIES.

A Practical System of Chemical Control for the Sugar Houses of Louisiana, the Tropics, and Other Cane-Producing Countries. By Irving H. Morse. 2d ed. rewritten. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 189 pp., 7x4 in., cloth, $2.

Intended for the technical superintendents, and chief chemists of sugar mills.

CHEMISTRY IN THE SERVICE OF MAN.

By Alexander Findlay. 2d ed. N. Y. and Lond., Longmans, Green and Co., 1917. 15+272 pp., 23 illus., 3 por., cloth, $2.

An account of some of the more important general principles and theories of chemical science, and of their industrial applications, intended for the general reader.

A certain amount of new matter has been added to this edition, including a new chapter on Fermentation and Enzyne Action.

ELECTRICAL ENGINEERING.

The Theory and Characteristics of Electrical Circuits and Machinery. By Clarence V. Christie. 2d ed., rev. and enl. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 20+546 pp., 508 illus., 9x6 in., cloth, $4.

Much new material has been added, the most important additions being sections on complex alternating waves and wave analysis, on polyphase alternating-current circuits, the construction of the characteristic curves of direct-current generators and motors, the design of direct and alternating-current machinery, the Blondel diagram for the synchronous motor, the symbolic method of analysis of the induction motor, alternating-current commutator motors, and a chapter on measuring instruments.

ELEMENTS OF MACHINE DESIGN.

By O. A. Leutwiler. N. Y., McGraw Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 15+607 pp. 339 illus., 9x6 in., cloth, $4.

Written to present in fairly completed form a discussion of the fundamental principles involved in the design and operation of machinery, and to outline or suggest methods of reasoning that may prove helpful in the design of various parts. Brief reviews are included of the more important straining actions to which machine parts are subjected and of the properties of the common materials used in machine construction and references to additional sources of information accompany the various chapters.

HENDRICKS' COMMERCIAL REGISTER OF THE UNITED STATES 1917–1918.

For Buyers and Sellers with which has been Incorporated the Assistant Buyer Especially Devoted to the Interests of the Architectural, Contracting, Electrical, Engineering, Hardware, Iron, Mechanical, Mill, Mining, Quarrying, Railroad, Steel and Kindred Industries. N. Y., S. E. Hendricks Co., Inc., 1917. 2227 pp., 10x8 in., cloth, $10.

Enlarged from the previous edition by over four hundred pages. Includes as a new section, an alphabetical list of the firms and individuals appearing in the classified Trades Section.

INGENIERIA DE FERROCARRILES.

La Teoria Y Practica Fundamental de Ferrocarriles, Desde La Concepcion del Idea Hasta La Terminacion del Trazo. Por Verne Leroy Havens. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd.; 1917. 10+357 pp., 48 illus., 1 diagram, 7x4 in., cloth. $3.50.

A pocketbook for railway surveyors and locating engineers in Latin America, intended to meet the need for such a work in Spanish. Covers the entire work, from the preliminary commercial

Digitized by Google

considerations to the final survey, including the documents and data required to accompany the surveys when submitted to South American governments.

LEARNING TO FLY IN THE U. S. ARMY.

A Manual of Aviation Practise. By E. N. Fales. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 9+180 pp., 39 illus., 1 pl., 7x5 in., leather, $1.50.

Parallels the instruction given under the author's direction in the U. S. Ground School of Military Aeronautics, University of Illinois branch. Sets forth for the non-technical student aviator, what he must know in order properly to understand his airplane, to keep it trued up and to operate it in cross country flights.

LIABILITY AND COMPENSATION INSURANCE.

Industrial Accidents and their Prevention, Employers' Liability, Workmen's Compensation, Insurance of Employers' Liability and Workmen's Compensation. By Ralph H. Blanchard. N. Y. and Lond., D. Appleton & Company; 1917. 12+394 pp., 13 illus., 8x5 in., cloth, $2.

Intended to present the results of the workmen's compensation movement in the United States in terms of legislation and insurance practise, and to explain the industrial accident problem and the development of liability and compensation principles as a background for the comprehension of present problems.

LUBRICATING ENGINEERS HANDBOOK.

A Reference Book of Data, Tables and General Information for the Use of Lubricating Engineers, Oil Salesmen, Operating Engineers, Mill and Power Plant Superintendents and Machinery Designers, etc. By John Rome Battle. Phila., and Lond., J. B. Lippincott Company, (copyright 1917). 333 pp., 114 illus., 9x6 in., cloth, $4.

Describes the properties of various lubricants and the methods of testing them, and discusses the proper methods of lubricating steam and gas engines, refrigerating machinery, railway cars, locomotives, rolling mills, pneumatic tools, etc.

MACHINE GUNS.

Part 1—Mechanism by Captain Julian S. Hatcher. Part 2—The Practical Handling of Machine Gun Fire by First Lieutenant Glenn P. Whilhelm, Part 3—Machine Gun Tactics by First Lieutenant Harry J. Malony. Menasha, George Banta Publishing Company, (copyright 1917). 233 pp., 84 illus., 3 diagrams, 8x5 in., cloth, $2.50.

The authors have been instructors in the Machine Gun School at Harlingen, Texas, since its establishment in 1916, and have based this manual on the notes made during their work. The guns described are the Benet-Mercié, the Lewis, the Maxim, the Vickers and the Colt.

MECHANICAL DRAWING PROBLEMS.

By Charles William Weick. N. Y., McGraw-Hill Book Co. Inc.; Lond., Hill Publishing Co., Ltd., 1917. 9+153 pp., 120 illus., 1 pl., 9x6 in., cloth, $1.25.

A book of examples and problems, intended to be used under the direction of a teacher. It aims to provide a large number of typical drawings carefully worked out as examples and accompanied by appropriate problems. These vary in difficulty sufficiently to enable the teacher to formulate suitable courses for all schools where mechanical drawing is taught.

OFFICE MANUAL INCLUDING POLICY BOOK AND STANDARD PRACTISE INSTRUCTIONS.

N. Y., A. W. Shaw Co., (copyright 1917). 50 pp., 10x8 in., cardboard.

A sample office manual supplementing Leffingwell's "Scientific Office Management" and intended to assist managers in preparing a manual for their own establishments.

OPERATION AND MAINTENANCE OF IRRIGATION SYSTEMS.

By S. T. Harding. N. Y., McGraw-Hill Book Company, Inc.; Lond., Hill Publishing Company, Ltd., 1917. 12+271 pp., 27 illus., 9x6 in., cloth, $2.50.

A discussion of the policies and methods used in the United States, in which the general principles are given with typical examples of their local applications. Contents: General Maintenance; Maintenance of Irrigation Systems; Organization for Operation and Maintenance-Methods of Delivering Irrigation Water; Measurement of Irrigation Water; Rules and Regulations; Payment for Construction and Operation Charges; General Operation; Operation and Maintenance Accounts; Rules and Regulations

PRACTICAL ELECTRIC ILLUMINATION.

By Terrell Croft. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 11+225 pp. 166 illus., 8x6 in., cloth, $2.

A concise account of the principles of illumination the methods employed and the proper ways of lighting indoor and outdoor spaces used for specific purposes. Contents: Preface; Funda

Digitized by Google

mental Ideas of Light Radiation; Principles and Units; Reflectors; Incandescent Lamps; Arc Lamps; Nernst, Mercury-Vapor and Tube Lamps; Principles of Illumination Design; Interior Illumination; Exterior Illumination.

PRACTICAL ROAD BUILDING.

By Charles E. Foote. Endorsed by the National Highways Association and the American Automobile Association. Philadelphia, David McKay, 1917. 13+295 pp., 40 illus., 7x5 in., cloth, $1.25.

A manual of information on the construction, maintenance and advantages of the various types of roads used in America, intended to summarize present day expert knowledge on the subject in a form intelligible to the general public.

PRACTICAL STRUCTURAL DESIGN.

A Text and Reference Work for Engineers, Architects, Builders, Draftsmen and Technical Schools; Especially Adapted to the Needs of Self-Tutored Men. By Ernest McCullough. N. Y., U. P. C. Book Company, Inc., 1917. 303 pp., 185 illus., 9x6 in., cloth, $2.50.

Based on a series of articles on the "Design of Beams, Girders and Trusses," which appeared in "Building Age" during 1914, but includes much additional material.

SCIENTIFIC OFFICE MANAGEMENT.

By W. H. Leffingwell. N. Y., Chic., Lond., A. W. Shaw Company, (copyright 1917) 253 pp., 32 illus., 3 diagrams, 11x9 in., cloth, $10.

A report on the results obtained by the author during ten years experience in the application to office work of the principles of the Taylor system, including planning, analysis, time and motion study, task and bonus plans, and the like. Gives a plan for applying the system.

STEAM BOILERS.

A Practical and Authoritative Discussion of Boiler Design and Construction, and the Development of Modern Types. Revised by Robert H. Kuss. Chicago, American Technical Society, 1917. 82 pp., 74 illus., 8x6 in., cloth, $1.

Covers in a Practical manner the methods of construction, the proper testing of materials and the methods of riveting and staying. Describes different types of stationary and marine boilers.

STEAM CHARTS.

And Special Tables for Turbine Calculations by F. O. Ellenwood. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd.; 1917. 49 pp., 18 charts, $1.

A series of charts and tables for the assistance of engineers when making calculations involving wet or superheated steam.

In the present edition, intended for those thoroughly conversant with the applications of the tables, the problems and explanatory matter have been eliminated. Tables giving the theoretical velocities of steam for each tenth of a heat unit up to 80 British thermal units, and the squares of numbers from 200 to 2000 have been added.

THE BUILDING ESTIMATOR'S REFERENCE BOOK.

A Practical and Thoroughly Reliable Reference Book for Contractors and Estimators Engaged in Estimating the Cost of and Constructing All Classes of Modern Buildings; Giving the Actual Labor Costs and Methods Employed in the Erection of Some of Our Present Day Structures, Together with All Necessary Material Prices and Labor Quantities Entering Into the Cost of All Classes of Buildings. By Frank R. Walker. 2d ed., rev. Chic., Frank R. Walker, 1917. 3535 pp., 7x5 in., leather, $5. (gift of the author.)

Presents costs compiled from the actual cost sheets, and chiefly from construction work under the author's supervision.

THE ESSENTIALS OF DESCRIPTIVE GEOMETRY.

By F. G. Higbee. 2d ed., rev. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 218 pp., 177 illus., 9x6 in., cloth, $1.80.

A text-book discussing the subject from the point of view of a draftsman, in which are included only those portions of it which possess industrial utility.

In addition to the correction and revision of the text of the first edition, a chapter on tangencies has been added.

THE J. E. ALDRED LECTURES ON ENGINEERING PRACTISE 1916–1917.

The Johns Hopkins University, Department of Engineering. Baltimore, The John Hopkins Press. 254 pp., 82 illus., 9 diagrams, 1 map, 9x6 in., pap. (gift of A. G. Christie)

Nine lectures delivered before the under-graduate engineering students of the University. The practical phases of engineering problems, rather than the underlying theory are given prominence. Contents: The Operation of a Hydro-Electric Plant, by A. E. Bauhan; Some

Digitized by Google

Things Engineers Should Know Concerning the Rudiments of Corporate Finance by Ralph D. Mershon; The Development of Power from the Standpoint of the Boiler Room, by C. F. Hirshfeld; Power and Service in Industrial Plants, by R. J. S. Pigott; Gas Manufacture, Construction, and Operation, by George P. Marrow; Rapid Transit Problems in American Cities, by George Staples Rice; Some Practical Problems Met with in the Design and Construction of Bridges and Similar Structures, by W. W. Pagon; Experimental Engineering, Particularly the Construction of Testing Stations on Water and Sewerage Problems, by Langdon Pearse; Public Utility Engineering and Finance, by Herbert A. Wagner.

THE PRINCIPLES OF AEROGRAPHY.

By Alexander McAdie. N.Y. and Chic., Rand McNally Co., (copyright 1917) 12+318 pp., 112 illus., 8x6 in., cloth, $3.

The author's especial aim has been to give prominence to the results of recent aerological investigations. The centimeter-gram-second system of units is employed. More than usual attention is given to cloud forms and the therodynamics of their formation and dissipation.

THE THEORY AND PRACTISE OF SCIENTIFIC MANAGEMENT.

By C. Bertrand Thompson. Bost., N. Y. and Chic., Houghton Mifflin Co.; 319 pp., 8x5 in., cloth, $1.75.

An attempt to present the facts concerning the subject and to appraise the movement as a whole. Contents; What Scientific Management Is; Frederick Winslow Taylor; Scientific Management in Practise; Economic Aspects of Scientific Management; the Literature of Scientific Management; Bibliography.

WATER-SUPPLY ENGINEERING.

The Designing and Constructing of Water-Supply Systems. By A. Prescott Folwell. 3d ed., rewritten. N. Y., John Wiley & Sons, Inc.; Lond., Chapman & Hall, Ltd., 1917. 15+484 pp., 121 illus., 9x6 in., cloth, $3.50.

In this edition the matter treating of water purification and the quality of water has been entirely rewritten at much greater length; that describing pumping machinery is practically new throughout, and hardly a paragraph of the original text has been used without some change calculated to bring the subject up to date. To avoid making the book too large, the text relating to construction has been condensed to a single chapter, and that dealing with maintenance and with hydraulics has been omitted.

WOOD AND OTHER ORGANIC STRUCTURAL MATERIALS.

By Charles Henry Snow. N. Y., McGraw-Hill Book Co., Inc.; Lond., Hill Publishing Co., Ltd., 1917. 18+478 pp., 90 illus., 9x6 in., cloth, $5.

The materials described are woods, paints and varnishes—with their associated oils, pigments gums and resins—glues, creosotes and india rubber. Presents the general as well as the physical characteristics of this group of materials, gives in convenient tabular form descriptions of the various woods, discusses the failure of wood because of age, decay, fire and animal attacks, and the methods of protection from these destructive agencies. Full bibliographic notes are given.

X-RAYS.

By G. W. C. Kaye. 2d ed. N. Y. and Lond., Longmans, Green, and Co., 1917. 17+285 pp., 115 illus., 9x6 in., cloth, $3.

By the head of the Radium and X-ray Department of the National Physical Laboratory. Written to give an account of such of the present-day methods and apparatus as appear valuable or novel, with a critical treatment of some of the features which have claimed the author's interest. The development of theory is discussed and a summary of the history of the X-ray, from 1895 to the middle of 1916 is included.

EMPLOYMENT BULLETIN

Vacancies The Institute is glad to learn of desirable vacancies from responsible sources, announcements of which will be published without charge in the BULLETIN The cooperation of the membership by notifying the Secretary of available positions, is particularly requested.

Men Available.—Under this heading brief announcements (not more than fifty words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Secretary's office not later than the 20th of the month if publication in the following issue is desired. All replies should be addressed to the number indicated in each case, and mailed to Institute headquarters.

VACANCIES

V-295. Commercial electrical and general engineer wanted for Havana, Cuba. He must be a technical graduate with at least two years practical and technical experience. Knowledge of Spanish desirable but not essential. Address giving complete details and

Digitized by Google

salary expected to P. O. Box 1260, New York City.

V-296. Wanted: Instructor in electrical engineering large eastern university. Special knowledge of electrical instruments and electrical measurements. Salary $1800.

V-297. Wanted: An energetic, wide-awake young man as instructor in the mechanical engineering department of a university in the Middle West. Applicant should be a graduate of a recognized technical college and have had some practical experience. Teaching experience desirable but not necessary.

V-298. Production manager wanted. Technical graduate preferred and one who has had practical experience in production of electrical machinery as well as in construction and laying out new buildings. Location near New York City. Position permanent. Salary about $2400.

V-299. Mechanical and electrical draftsmen wanted. Men familiar with the design of D-C. apparatus, motors, ranging as high as 1000 h.p. Technical graduates preferred. Location in vicinity of New York City.

V-300. Operating man with marked executive ability who has been in charge of hydro-electric station for position of chief operator. Must be familiar with advanced operating methods in large stations on high voltage transmission system. Must have had experience in handling electrical construction and maintenance.

V-301. Junior draftsman with some shop and drafting experience for power plant and installation drafting. Salary about $100 per month.

V-302. High salary paid man capable managing and developing distribution of 75,000 kw. load, vicinity Barcelona, Spain. Must show records important positions previously held with wide experience construction and management electrical systems. Must be over 30 and speak Spanish. Man receiving at present under $5,000 not considered.

V-303. Wanted: Skilled man to take charge of the assembly of lighting and power transformers. Apply, stating experience, and salary expected, to Canadian General Electric Co., Limited, Peterborough, Ontario.

V-304. Mechanical superintendent wanted. Must be competent to handle and direct construction, installation and maintenance of buildings, machinery and equipment, also power plant operation. Jurisdiction will cover several plants. Only high calibered men need apply. In order to receive consideration must outline fully past experience, age, salary, credentials.

V-305. Engineer experienced in power station design, operation and efficiency; location New York.

V-306. Engineer experienced power station construction; must be familiar with modern steam power stations, construction and operation, including high-tension systems; location Ohio.

V-307. Wanted. A college graduate in electrical engineering with one or two years' experience for work along technical lines in a permanent position on telephone office equipment in Buffalo, N. Y. Will pay $16.00 per week for man with one year's experience and $18.00 per week for man with two years' experience. Address communications to Telephone Company 297 Michigan St., Buffalo, N. Y.

MEN AVAILABLE

857. Electrical engineer, chief draftsman, manufacturing engineer and construction ten years. Holding company two years. With consulting engineers last five years. Rates, valuations, distribution and special financial statistical experience. Position desired New York or vicinity with investment house or industrial corporation in war work. Married, age 39. Minimum salary $3000.

858. Electrical technical graduate, age 25. Five years' practical experience, mostly power plant and substation installations. Desires position with lighting or power company, commercial end preferred, with good chance for advancement. Location no object; willing to travel. Detailed information furnished on request.

859. Electrical engineer, six years' experience on electric power generation and distribution, two and a half years of this with Niagara Falls Power Company. At present in charge of electric system of a large government institution. Will consider change on a month's notice to present employers. Married; age 29; salary $2400.

860. Executive position, central station or manufacturing company, by married man, eighteen years' experience American and European practice in design, construction, operation steam and hydro power plants, distribution systems, overhead and underground. Executive in charge power sales department, wholesale power distributors. Wide experience in organization and systematizing.

Digitized by Google

861. Electrical engineer, technical graduate, with broad practical engineering experience. Well versed in power plants and transmission line work and the utilization of electric power. At present electrical engineer for large steam railroad system. Desire position with consulting engineer or operating company in Ohio or adjoining states. Age 35; salary $1800.

862. High class electrical engineer of wide experience and highest references, age 29, seeks position corresponding to training and capacity. Experienced in all classes of high-frequency, telephone and electrochemical work, as well as in general electrical engineering. Unqualified references to both ability and loyalty.

863. Electrical engineer, technical graduate, married, six years' experience shop, test and road work, electrical apparatus and turbines for large manufacturing company; construction and operation of steam and hydroelectric power plants, substations and high tension transmission systems. Present salary $2400.

864. Technical graduate, electrical engineering, with two years' laboratory and teaching experience, desires position as research engineer, or as teacher of electrical engineering, preferably laboratory work. Available after Dec. 1. Salary $1600. Married.

865. Electrical engineer, technical graduate, with specialized training in hydraulic and hydroelectric engineering and transmission line problems, desires position where ability in this class of work is wanted. Member A. I. E. E. and N. E. L. A. Married, age 30. Now employed as electrical engineer at $2300. Correspondence invited.

866. Electrical engineer, at present employed, eighteen years' experience in construction, electrical power generation, transmission and distribution, wishes an executive position with growing company offering chance of advancement to an efficient worker. Reason for desiring change salary incommensurate with knowledge required and responsibilities imposed. Might take financial interest.

867. Electrical Engineer, 30 years of age; 12 years' experience, technical education, first class draughtsman, expert electrician, design, operation or construction of hydroelectric plants E. H. T. or L. T., also electric railway experience. Desires permanent responsible position with future prospects. Married. Used to handling men. A 1 references. Salary $1800 minimum.

868. Executive Engineer. Broad experience on power, lighting and railway systems; high tension transmission, public utility valuations. Factory production, industrial development.

869. Electrical Engineer, age 30, university graduate, 6 years' experience in design, construction and operation of power plants, substations, overhead and underground distributing systems. Have been employed by large public utility corporations as designing and assistant engineer. Now employed. Will go anywhere.

870. Technical University graduate, electrical and mechanical engineer with two years' experience along electrical and mechanical manufacturing lines and one year experience in time and motion study, is desirous of a permanent location in the southern New England states with a progressive manufacturing company. Salary $1500 to $2000. Available upon 30 days notice to present employer.

871. Superintendent of medium or superintendent of distribution of large electric utility. Technical training, ample experience, best of references. Available at once.

Digitized by Google

OFFICERS AND BOARD OF DIRECTORS, 1917-1918.

PRESIDENT.
(Term expires July 31, 1918)
E. W. RICE, Jr.

JUNIOR PAST-PRESIDENTS.

(Term expires July 31, 1918)
JOHN J. CARTY

(Term expires July 31, 1919)
H. W. BUCK

VICE-PRESIDENTS.
(Term expires July 31, 1918)

B. A. BEHREND
P. JUNKERSFELD
L. T. ROBINSON
FREDERICK BEDELL
A. S. McALLISTER
JOHN H. FINNEY

MANAGERS.

(Term expires July 31, 1918)
F. B. JEWETT
JOHN B. TAYLOR
HAROLD PENDER

(Term expires July 31, 1919)
C. E. SKINNER
JOHN B. FISKEN
N. A. CARLE

(Term expires July 31, 1920)
CHARLES S. RUFFNER
CHARLES ROBBINS
E. H. MARTINDALE

(Term expires July 31, 1921)
WALTER A. HALL
WILLIAM A. DEL MAR
WILFRED SYKES

TREASURER (Term expires July 31, 1918) **SECRETARY.**
GEORGE A. HAMILTON F. L. HUTCHINSON

HONORARY SECRETARY
RALPH W. POPE

LIBRARIAN
HARRISON W. CRAVER

GENERAL COUNSEL.
PARKER and AARON,
52 Broadway, New York.

PAST PRESIDENTS.—1884-1917.

*NORVIN GREEN, 1884-5-6.
*FRANKLIN L. POPE, 1886-7.
T. COMMERFORD MARTIN, 1887-8.
EDWARD WESTON, 1888-9.
ELIHU THOMSON, 1889-90.
*WILLIAM A. ANTHONY, 1890-91.
ALEXANDER GRAHAM BELL, 1891-92.
FRANK JULIAN SPRAGUE, 1892-3.
*EDWIN J. HOUSTON, 1893-4-5.
*LOUIS DUNCAN, 1895-6-7.
FRANCIS BACON CROCKER, 1897-8.
A. E. KENNELLY, 1898-1900.
CARL HERING, 1900-1.
CHARLES P. STEINMETZ, 1901-02.
CHARLES F. SCOTT, 1902-3.
BION J. ARNOLD, 1903-4.
JOHN W. LIEB, 1904-5.
SCHUYLER SKAATS WHEELER, 1905-6.
SAMUEL SHELDON, 1906-7.
*HENRY G. STOTT, 1907-8.
LOUIS A. FERGUSON, 1908-09.
LEWIS B. STILLWELL, 1909-10.
DUGALD C. JACKSON, 1910-11.
GANO DUNN, 1911-12.
RALPH D. MERSHON, 1912-13.
C. O. MAILLOUX, 1913-14.
PAUL M. LINCOLN, 1914-15.
JOHN J. CARTY, 1915-16.
H. W. BUCK, 1916-17.

*Deceased.

Digitized by Google

INSTITUTE COMMITTEES.

Revised to October 1, 1917.

GENERAL STANDING COMMITTEES.

EXECUTIVE COMMITTEE.

E. W. Rice, Jr., Chairman,
General Electric Company, Schenectady, N. Y.
H. W. Buck, Harold Pender,
N. A. Carle, L. T. Robinson,
George A. Hamilton, C. E. Skinner.

FINANCE COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
Walter A. Hall, Charles Robbins.

MEETINGS AND PAPERS COMMITTEE

L. T. Robinson, Chairman,
General Electric Company, Schenectady, N. Y.
L. W. Chubb, Secretary,
Westinghouse E. and M. Company, Pittsburgh, Pa.
B. A. Behrend, Harris J. Ryan,
W. I. Slichter,
and the chairmen of the technical committees

EDITING COMMITTEE.

W. I. Slichter, Chairman,
Columbia University, New York.
M. G. Lloyd, L. T. Robinson,
Henry H. Norris, C. E. Skinner.

CODE COMMITTEE.

Farley Osgood, Chairman,
80 Park Place, Newark, N. J.
J. C. Forsyth, H. R. Sargent,
H. B. Gear, G. A. Sawin,
A. H. Griswold, A. M. Schoen,
H. O. Lacount, George F. Sever,
Johnston Livingston, C. E. Skinner,
Henry N. Muller, H. S. Warren.

BOARD OF EXAMINERS.

A. S. McAllister, Chairman,
261 West 23rd St., New York.
William McClellan, F. L. Rhodes,
Henry H. Norris, W. I. Slichter.

SECTIONS COMMITTEE.

Walter A. Hall, Chairman,
General Electric Company, West Lynn, Mass.
P. H. Daggett, Vice-Chairman
John B. Fisken, H. W. Flashman,
A. M. Schoen,
and the chairmen of all Institute Sections, *ex-officio.*

COMMITTEE ON STUDENT BRANCHES.

(Sub-Committee of Sections Committee.)
P. H. Daggett, Chairman,
University of North Carolina, Chapel Hill, N. C.
Alexander M. Gray, A. C. Lanier,
C. Francis Harding, Charles F. Scott.

MEMBERSHIP COMMITTEE.

H. A. Pratt, Chairman,
W. E. and M. Company, 165 Broadway, N. Y.
T. F. Barton, Wills MacLachlan,
H. Goodwin, Jr., H. R. Woodrow.

PUBLIC POLICY COMMITTEE.

Calvert Townley, Chairman,
W. E. and M. Company,
165 Broadway, New York.
H. W. Buck, P. Junkersfeld,
N. A. Carle, John W. Lieb,
John J. Carty, E. W. Rice, Jr.,
C. E. Skinner.

HEADQUARTERS COMMITTEE.

N. A. Carle, Chairman,
Public Service Electric Company, Newark, N. J.
A. S. McAllister, F. L. Hutchinson.

STANDARDS COMMITTEE.

C. A. Adams, Chairman,
Massachusetts Institute of Technology, Cambridge, Mass.
Harold Pender, Secretary,
University of Pennsylvania, Philadelphia, Pa.
P. G. Agnew, W. S. Gorsuch,
Frederick Bedell, F. C. Hanker,
Joseph Bijur, H. M. Hobart,
L. F. Blume, P. Junkersfeld,
James Burke, A. E. Kennelly,
G. A. Burnham, G. L. Knight,
N. A. Carle, F. A. Laws,
P. H. Chase, A. S. McAllister,
E. J. Cheney, W. L. Merrill,
H. H. Clark, Charles Robbins,
E. H. Colpitts, L. T. Robinson,
F. P. Cox, C. H. Sharp,
William A. Del Mar, C. E. Skinner,
A. M. Dudley, N. W. Storer,
E. J. Edwards, John B. Taylor,
H. W. Fisher, R. B. Williamson.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION.

C. O. Mailloux, President,
20 Nassau St., New York.
F. B. Crocker, Vice-President,
A. E. Kennelly, Secretary,
Harvard University, Cambridge, Mass.
C. A. Adams, A. S. McAllister,
B. A. Behrend, M. I. Pupin,
James Burke, E. B. Rosa,
John J. Carty, David B. Rushmore,
Gano Dunn, Charles P. Scott,
H. M. Hobart; Clayton H. Sharp,
John W. Lieb, C. E. Skinner,
Elihu Thomson.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT.

George F. Sever, Chairman,
13 Park Row, New York.
A. H. Babcock, A. S. McAllister,
Gano Dunn, Schuyler Skaats Wheeler

EDISON MEDAL COMMITTEE.

Appointed by the President for terms of five years.

Term expires July 31, 1918.
H. W. Buck, F. A. Scheffler,
J. Franklin Stevens.
Term expires July 31, 1919.
Charles F. Brush. C. C. Chesney.
N. W. Storer,
Term expires July 31, 1920.
Carl Hering, Harris J. Ryan,
Robert Lindsay.
Term expires July 31, 1921.
W. C. L. Eglin, Bancroft Gherardi,
E. W. Rice, Jr.
Term expires July 31, 1922.
C. A. Adams, L. A. Ferguson,
S. W. Stratton.

Elected by the Board of Directors from its own membership for terms of two years.

Term expires July 31, 1918.
L. T. Robinson, Harold Pender,
C. E. Skinner.
Term expires July 31, 1919.
B. A. Behrend, Frederick Bedell,
A. S. McAllister.

Ex-Officio.

E. W. Rice, Jr., President,
George A. Hamilton, Treasurer,
F. L. Hutchinson, Secretary.

Digitized by Google

TECHNICAL COMMITTEES.

Revised to October 1, 1917.

POWER STATIONS.

Philip Torchio, Chairman,
N. Y. Edison Company, 124 E. 15th St., New York.

L. P. Crecelius,	H. S. Putnam,
W. S. Gorsuch,	F. A. Scheffler,
P. M. Lincoln,	R. F. Schuchardt,
S. A. Moss,	H. L. Wallau,
I. E. Moultrop,	W. F. Wells,

B. F. Wood.

TRANSMISSION AND DISTRIBUTION.

L. E. Imlay, Chairman,
Niagara Falls Power Company, Niagara Falls, N. Y.

A. O. Austin,	P. M. Lincoln,
J. A. Brundige,	L. C. Nicholson,
H. W. Buck,	W. D. Peaslee,
Wallace S. Clark,	D. W. Roper,
E. E. F. Creighton,	Harris J. Ryan,
H. W. Fisher,	P. H. Thomas.

TRACTION AND TRANSPORTATION.

N. W. Storer, Chairman,
Westinghouse E. & M. Co., East Pittsburgh, Pa.

Harry H. Adams,	William A. Del Mar,
A. H. Armstrong,	J. V. B. Duer,
A. H. Babcock,	John Murphy,
Reinier Beeuwkes,	Charles F. Scott,
W. H. Blood, Jr.,	H. M. Warren.

INDUSTRIAL AND DOMESTIC POWER.

E. H. Martindale, Chairman,
National Carbon Company, Cleveland, O.
A. G. Pierce, Vice-Chairman,
2211 Farmers Bank Building, Pittsburgh, Pa.

H. W. Cope,	Charles D. Knight,
James Dixon,	A. M. MacCutcheon,
A. M. Dudley,	James M. Smith,
R. H. Goodwillie,	H. Weichsel,
A. L. Hadley,	J. B. Wiard,
C. A. Kelsey,	R. B. Williamson.

LIGHTING AND ILLUMINATION.

Edward P. Hyde, Chairman,
Nela Park, Cleveland, O.

G. N. Chamberlin,	R. C. Powell,
C. E. Clewell,	E. B. Rosa,
J. R. Cravath,	W. D'A. Ryan,
Bassett Jones,	Clayton H. Sharp,
T. S. Perkins,	W. M. Skiff.

ECONOMICS OF ELECTRIC SERVICE

W. B. Jackson, Chairman,
Harris Trust Building, Chicago, Ill.

P. H. Bartlett,	Leavitt L. Edgar,
Philander Betts,	W. S. Gorsuch,
W. H. Blood, Jr.,	Ralph G. Hudson,
Fred A. Bryan,	A. H. Kruesi,
C. L. Cory,	Allard Smith.

PROTECTIVE DEVICES.

D. W. Roper, Chairman,
Commonwealth Edison Company, 72 W. Adams St., Chicago, Ill.

E. E. F. Creighton,	P. M. Lincoln,
Leslie N. Crichton,	A. A. Meyer,
James C. Dow,	N. L. Pollard,
L. L. Elden,	F. E. Ricketts,
E. M. Hewlett,	Philip Torchio,

H. R. Woodrow.

ELECTROCHEMISTRY AND ELECTRO-METALLURGY.

F. A. J. Fitzgerald, Chairman,
Fitzgerald Laboratories, Niagara Falls, N. Y.

Lawrence Addicks,	F. A. Lidbury,
Joseph L. Dixon,	T. H. Schoepf,
I. R. Edmands,	J. A. Seede,
Carl Hering,	Willis R. Whitney.

ELECTROPHYSICS.

Frederick Bedell, Chairman,
Cornell University, Ithaca, N. Y.

H. D. Arnold,	F. W. Peek, Jr.
A. C. Crehore,	L. T. Robinson,
E. P. Hyde,	E. B. Rosa,
P. S. Millar,	C. E. Skinner.

TELEGRAPHY AND TELEPHONY.

L. F. Morehouse, Chairman,
A. T. and T. Company, 195 Broadway, New York.

E. F. W. Alexanderson,	William Maver,
R. E. Chetwood,	Kempster B. Miller,
E. B. Craft,	John Stone Stone,
M. M. Davis,	John B. Taylor,
A. H. Griswold,	J. L. Wayne.

MARINE.

H. A. Hornor, Chairman,
Hamilton Court, 39th and Chestnut Streets, Philadelphia, Pa.
D. M. Mahood, Secretary,
Sperry Gyroscope Company,
Manhattan Bridge Plaza, Brooklyn, N. Y.

R. B. Chillas, Jr.,	Guy Hill,
M. W. Day,	O. P. Loomis,
L. A. Doggett,	G. A. Pierce, Jr.,
G. E. Edgar,	H. M. Southgate,
W. L. R. Emmet,	E. A. Sperry,
W. R. Furlong,	Wilfred Sykes,
H. L. Hibbard,	F. W. Wood.

USE OF ELECTRICITY IN MINES.

K. A. Pauly, Chairman,
General Electric Company, Schenectady, N.Y.

Frank H. Armstrong,	L. C Ilsley,
Graham Bright,	R. L. Kingsland,
W. A. Chandler,	A. B. Kiser,
H. H. Clark	Charles Legrand,
F. J. Duffy,	Charles M. Means,

H. M. Warren.

ELECTRICAL MACHINERY.

Alexander M. Gray, Chairman,
Cornell University, Ithaca, N. Y.

B. A. Behrend,	H. F. T. Erben,
A. M. Dudley	R. B. Williamson,

James Burke.

INSTRUMENTS AND MEASUREMENTS.

S. G. Rhodes, Chairman,
104 East 32nd St., New York.

P. G. Agnew,	F. V. Magalhaes,
F. P. Cox,	T. S. Perkins,

Clayton H. Sharp.

IRON AND STEEL INDUSTRY.

F. D. Egan, Chairman,
Pittsburgh Crucible Steel Co., Midland, Pa.

F. B. Crosby,	J. C. Reed,
Eugene Friedlaender,	A. G. Pierce,
E. S. Jefferies,	Wilfred Sykes,
W. C. Kennedy,	R. Tencher
D. M. Petty,	R. B. Williamson,

J. H. Wilson.

EDUCATIONAL.

E. J. Berg, Chairman,
Union College, Schenectady, N. Y.

Alexander M. Gray,	E. B. Merriam,
Charles S. Howe,	Chester W. Rice,
E. A. Loew,	C. E. Skinner,

W. I. Slichter.

Digitized by Google

INSTITUTE REPRESENTATIVES.

ON BOARD OF AWARD, JOHN FRITZ MEDAL.

C. O. Mailloux, John J. Carty.
Paul M. Lincoln, H. W. Buck.

ON BOARD OF TRUSTEES, UNITED ENGINEERING SOCIETY.

Gano Dunn, Samuel Sheldon,
Calvert Townley.

ON LIBRARY BOARD OF UNITED ENGINEERING SOCIETY.

W. I. Slichter, Edward D. Adams,
Harold Pender, Samuel Sheldon,
F. L. Hutchinson.

ON ELECTRICAL COMMITTEE OF NATIONAL FIRE PROTECTION ASSOCIATION.

The chairman of the Institute's Code Committee.

ON JOINT COMMITTEE ON ENGINEERING EDUCATION.

Charles F. Scott, Samuel Sheldon.

ON COUNCIL OF AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

W. S. Franklin, G. W. Pierce.

ON ADVISORY BOARD OF AMERICAN YEAR-BOOK.

Edward Caldwell.

ON U. S. NATIONAL COMMITTEE OF THE INTERNATIONAL ILLUMINATION COMMISSION.

A. E. Kennelly, C. O. Mailloux,
Clayton H. Sharp.

ON JOINT COMMITTEE ON CLASSIFICATION OF TECHNICAL LITERATURE.

F. B. Jewett.

ON PAN-AMERICAN ENGINEERING COMMITTEE.

Gano Dunn, William McClellan,
John H. Finney Charles W. Stone,
Calvert Townley.

ON NATIONAL JOINT COMMITTEE ON OVERHEAD AND UNDERGROUND LINE CONSTRUCTION.

Farley Osgood, Percy H. Thomas.

AMERICAN COMMITTEE ON ELECTROLYSIS.

Bion J. Arnold, F. N. Waterman,
Paul Winsor.

ON ENGINEERING COUNCIL.

H. W. Buck, N. A. Carle,
E. W. Rice, Jr., P. Junkersfeld,
C. E. Skinner.

ENGINEERING COMMITTEE OF THE NATIONAL RESEARCH COUNCIL.

F. B. Jewett, Clayton H. Sharp.

ON ENGINEERING FOUNDATION BOARD.

Michael I. Pupin.

ON NAVAL CONSULTING BOARD.

Benjamin G. Lamme, Frank J. Sprague.

ON AMERICAN ENGINEERING STANDARDS

C. A. Adams, N. A. Carle,
P. Junkersfeld.

COMMITTEE ON GENERAL ENGINEERING, ADVISORY COMMISSION OF THE COUNCIL OF NATIONAL DEFENSE.

H. W. Buck, C. A. Adams.

COMMISSION OF WASHINGTON AWARD.

John Price Jackson, Charles F. Scott.

LOCAL HONORARY SECRETARIES.

Guido Semenza, N. 10 Via S. Radegonda, Milan, Italy.
Robert Julian Scott, Christchurch, New Zealand,
T. P. Strickland, N. S. W. Government Railways Sydney, N. S. W.
W. G. T. Goodman, Adelaide, South Australia.
James S. Fitzmaurice, Perth, West Australia.
L. A. Herdt, McGill Univ., Montreal, Que.
Henry Graftio, Petrograd, Russia.
A. S. Garfield, 45 Boulevard Beausejour Paris 16 E. France.
Harry Parker Gibbs, Tata Hydroelectric Power Supply Co., Ltd., Bombay, India.
John W. Kirkland, Johannesburg, South Africa.

Digitized by Google

LIST OF SECTIONS

Revised to October, 1917.

Name and when Organized	Chairman	Secretary
Atlanta.....Jan. 19, '04	A. M. Schoen	Thomas C. Taliaferro, S. E. Underwriters Ass'n., Atlanta, Ga.
Baltimore.....Dec. 16, '04	J. B. Whitehead	L.M.Potts,Industrial Bldg.,Baltimore,Md.
Boston.....Feb. 13, '03	H. M. Hope	Ira M. Cushing,84 State St.,Boston,Mass.
Chicago.....1893	Wm. J. Crumpton	C.A.Keller,Edison Building, Chicago, Ill.
Cleveland.....Sept. 27, '07	C. M. Rakestraw	C. S. Ripley, 711 Williamson Building, Cleveland, Ohio.
Denver.....May 18, '15	Norman Read	Robert B. Bonney, 806 Telephone Building, Denver, Colo.
Detroit-Ann Arbor.....Jan. 13, '11	H. H. Higbie	H. J. Wyckoff, Detroit Edison Company, Detroit, Mich.
Fort Wayne.....Aug. 14, '08	J. J. Kline	R. B. Roberts, G. E. Co., Fort Wayne,Ind.
Indianapolis-Lafayette..Jan. 12, '12	H. O. Garman	D. J. Angus, Esterline and Angus, Indianapolis, Ind.
Ithaca.....Oct. 15, '02	F. Bedell	Alexander Gray,CornellUniv.,Ithaca,N.Y.
Kansas City, Mo......Apr. 14, '16	W. F. Barnes	W. F. Barnes, 1012 Baltimore Ave., Kansas City, Mo.
Los Angeles.....May 19, '08	Don Morgan	A. W. Nye, University of Southern California, Los Angeles, Cal.
Lynn.....Aug. 22, '11	J. M. Davis	R. D. Thomson, General Electric Company, West Lynn, Mass.
Madison.....Jan. 8, '09	J. R. Price	L. E. A. Kelso, University of Wisconsin, Madison, Wis.
Mexico.....Dec. 13, '07		
Milwaukee.....Feb. 11, '10	Arthur Simon	Soren H. Mortensen, Allis-Chalmers Mfg. Co., West Allis, Wis.
Minnesota.....Apr. 7, '02	F. W. Springer	A. B. King, Electric Machinery Company, Minneapolis, Minn.
Panama.....Oct. 10, '13	C. J. Embree	William F. Connell, Balboa Heights, C. Z.
Philadelphia.....Feb. 18, '03	Nathan Hayward	H. Mouradian, Bell Telephone Co. of Penna., Philadelphia, Pa.
Pittsburgh.....Oct. 13, '02	F. E. Wynne	G. M. Baker, G. E. Co., Oliver Building, Pittsburgh, Pa.
Pittsfield.....Mar. 25, '04	F. F. Brand	E. H. Branson, General Electric Company, Pittsfield, Mass.
Portland, Ore......May 18, '09	E. D. Searing	R. M. Boykin, North Coast Power Co., Portland, Oregon.
Rochester.....Oct. 9, '14	Frank C. Taylor	C. T. Wallis, 138 Fairview Avenue, Rochester, N. Y.
St. Louis.....Jan. 14, '03	A.McR.Harrelson	H. L. Hope, Southwestern Bell Telephone System, St. Louis, Mo.
San Francisco.....Dec. 23, '04	L. R. Jorgensen	A. G. Jones, 811 Rialto Building, San Francisco, Cal.
Schenectady.....Jan. 26, '03	W. L. Upson	L. F. Millham, General Electric Company, Schenectady, N. Y.
Seattle.....Jan. 19, '04	C. E. Magnusson	C. F. Terrell, Puget Sound Trac. Lt. and Power Co., Seattle, Wash.
Spokane.....Feb. 14, '13	Charles A. Lund	J. E. E. Royer, Washington Water Power Company, Spokane, Wash.
Toledo.....June 3, '07	W. E. Richards	Max Neuber, 1257 Fernwood Ave., Toledo, Ohio.
Toronto.....Sept. 30, '03	William G.Gordon	Ernest V. Pannell, 60 Front Street, West, Toronto, Ont.
Utah Section.....Mar. 9, '17	A. S. Peters	H. T. Plumb, Newhouse Bldg., Salt Lake City, Utah.
Urbana.....Nov. 25, '02	L. V. James	A. R. Knight, Univ of Illinois, Urbana,Ill,
Vancouver.....Aug. 22, '11	R. F. Hayward	T. H. Crosby, Canadian Westinghouse Co. Vancouver, B. C
Washington, D. C......Apr. 9, '03	Paul G. Agnew	J. Ernest Smith, McKinley Manual Training School, Washington, D. C.

Total 33

LIST OF BRANCHES

Name and when Organized	Chairman	Secretary
Agricultural and Mech. College of Texas.....Nov. 12, '09	L. E. Tighe	F. V. Murrah, College Station, Tex.
Alabama Poly. Inst......Nov. 10, '16	W. W. Hill	J. A. Douglas, P.O. Box 190, Auburn, Ala.
Alabama, Univ. of.....Dec. 11, '14	Gustav Wittig	A. F. Frazer, University, Ala.
Arkansas, Univ. of.....Mar. 25, '04	E. P. O'Neal	J. C. Douthit, University of Arkansas, Fayetteville, Ark.
Armour Institute.....Feb. 26, '04	R. A. Newlander	A. A. Hofgren, 7542 So. Chicago Ave., Chicago, Ill.
Brooklyn Poly. Inst......Jan. 14, '16	Paul G. Wehle	Robert Davie, The Polytechnic Institute, Brooklyn, N. Y.
Bucknell University.....May 17, '10	A. W. Hatfield	C. C. Gillette, Phi Gamma Delta House, Bucknell University, Lewisburg, Pa.
California, Univ. of.....Feb. 9, '12	A. J. Swank	G. F. Teale, University of California, Berkeley, Cal.
Carnegie Inst. of Tech...May 18, '15	W. F. Eames	B. C. Dennison, Carnegie School of Technology, Pittsburgh, Pa.
Cincinnati, Univ. of.....Apr. 10, '08	R. L. Utley	H. V. McCormick, 3110 Woodburn Ave., Cincinnati, Ohio
Clarkson Col. of Tech....Dec. 10, '15	R. H. Hoyt	E. S. Parks, Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural Col. Nov. 8, '12	D. H. Banks	W. H. Neil, Clemson College, S. C.
Colorado State Agricultural College.....Feb. 11, '10	R. C. Richards	W. A. Stallings, Colorado State Agricultural College, Fort Collins, Colo.

Digitized by Google

LIST OF BRANCHES—Continued.

Name and when Organized	Chairman	Secretary
Colorado, Univ. of.....Dec. 16, '04	Robert Newman	William N. Gittings, University of Colorado, Boulder, Colo.
Georgia School of Technology.....June 25, '14	R. E. Robinson	John Farago, Georgia School of Technology, Atlanta, Ga.
Highland Park College.Oct. 11, '12	E. E. Gould	Adolph Shane, Highland Park College, Des Moines, Iowa.
Idaho, Univ of.....June 25, '14	D. Nankervis	L.J.Corbett,Univ.of Idaho,Moscow,Idaho.
Iowa State College.....Apr. 15, '03	C. L. Merrick	F. A. Robbins, Iowa St.Col., Ames, Iowa.
Iowa, Univ. of.....May 18, '09		A. H. Ford, University of Iowa, Iowa City, Iowa.
Kansas State Agr. Col...Jan. 10, '08	L. N. Miller	M. H. Russell, Kansas State Agri. Col., Manhattan, Kansas.
Kansas Univ. of.....Mar. 18, '08	Clarence Lynn	Robert W. Warner, 1428 Tennessee Street, Lawrence, Mass.
Kentucky, State Univ. of Oct. 14, '10	A. W. Davies	G. D. Aaron,State University of Kentucky, Lexington, Ky.
Lafayette College.....Apr. 5, '12	Harry C. Hartung	William Lash Lipps, 633 Parsons, Easton, Pa.
Lehigh University.....Oct. 15, '02	R. H. Lindsay	R. D. Bean, 40 N. 7th Ave., Bethlehem, Pa.
Lewis Institute.....Nov. 8, '07	Rowland Manley	S. P. McDaniels, Lewis Institute, Chicago.
Maine Univ. of.....Dec. 26, '06	Fred P. Jones	G. K. Wadlin, Lambda Chi Alpha House, Orono, Maine.
Massachusetts Inst. of Tech......Apr. 13, '17		
Michigan, Univ. of.....Mar. 25, '04	W. R. Harvey	T. W. Connant, University of Michigan, Ann Arbor, Mich.
Minnesota, Univ. of.....May 16, '16	George W. Miller	Ray McKibben, University of Minnesota, Minneapolis, Minn.
Missouri Univ. of.....Jan. 10, '03	A. C. Lanier	D. P. Savant, University of Missouri, Columbia, Mo.
Montana State Col.....May 21, '07	Roy C. Hagen	J. A. Thaler, Montana State College, Bozeman, Mont.
Nebraska, Univ. of.....Apr. 10, '08	Olin J. Ferguson	Oskar E. Edison, University of Nebraska, Lincoln, Nebraska...
North Carolina Col. of Agr. and Mech. Arts..Feb. 11, '10	John R. Hauser	Landon C. Flournoy, N. C. Coll. of A. and M. Arts, West Raleigh, N. C.
North Carolina, Univ. of.Oct. 9, '14	A. C. Forney	C. N. Sloan, Univ. of North Carolina, Chapel Hill, N. C.
North Dakota, Univ. of..Feb. 15, '17	D. F. McConnell	Roy A. Wehe, University ,N. D.
Norwich University.....June 28, '16	Edward B. Dawson	Robin Beach, Norwich University, Northfield, Vt.
Ohio Northern Univ.....Feb. 9, '12	W. F. Parsons	A. J. Ferlic, 718 N. Main Street Ada, Ohio.
Ohio State University...Dec. 20, '02	E. S. Gunn	T. D. Robb, 124 West 10th Ave., Columbus, Ohio.
Oklahoma Agricultural and Mech. Col.....Oct. 13, '11	G. E. Davis	W. C. Lane, Oklahoma A. and M. College, Stillwater, Okla.
Oklahoma, Univ. of.....Oct. 11, '12	A. W. Walter	C. H. Whitwell, University of Oklahoma, Norman, Okla.
Oregon Agr. Col.....Mar. 24, '08	L. Happold	Lawrence Fudge, Oregon Agri. College, Corvallis, Ore.
Penn. State College....Dec. 20, '02	H. A. Billig	P. J. F. Derr, State College, Pa.
Pittsburgh, Univ. of....Feb. 26, '14	E. R. Roth	W. B. Forman, University of Pittsburgh, Pittsburgh, Pa.
Purdue University.....Jan. 26, '03	C. F. Harding	A. N. Topping, Purdue Univ., Lafayette, Indiana.
Rensselaer Poly. Inst....Nov. 12, '09	W. J. Williams	Leroy C. Witt, Rensselaer Polytechnic Institute, Troy, N. Y.
Rose Polytechnic Inst....Nov. 10, '11	H. E. Smock	Sam P. Stone, 1012 North 8th Street, Terra Haute, Ind.
Rhode Island State Col..Mar. 14, '13		
Stanford Univ.....Dec. 13, '07	H. W. Lewis	A. L. Morgan, Stanford University, Cal.
Syracuse Univ.....Feb. 24, '05	W. P. Graham	R. A. Porter, Syracuse University, Syracuse, N. Y.
Texas, Univ. of.....Feb. 14, '08	J. W. Ramsay	J. A. Correll, Univ. of Texas, Austin, Tex.
Throop College of Technology.....Oct. 14, '10	J. Paul Youtz	Clark E. Baker,Throop Dormitory,Throop College of Technology, Pasadena, Cal.
Virginia Polytechnic Institute.....Jan. 8, '15	Baxter McIntosh	J. A. Carr, Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, Univ. of.....Feb. 9, '12	Charles Henderson	J.Arthur Evans, University, Va.
Wash., State Col. of.....Dec. 13, '07	S. Stites	E. Tollefson, State Coll. of Wash., Pullman, Wash.
Washington Univ.....Feb. 5, '04		R. W. Mac Donald, Washington University, St. Louis, Mo.
Washington, Univ. of...Dec. 13, '12	L. P. Kongsted	L. M. Lubcke, University of Washington, Seattle, Wash.
West Virginia Univ.....Nov. 13, '14	O. P. Joliffe	D. F Cronin, 52 University Driveway Morgantown, W. Va.
Worcester Poly. Inst....Mar. 25, '04	B. Luther	N. L. Towle, Worcester Polytechnic Institute, Worcester, Mass.
Yale University.....Oct. 13, '11	B. P. O'Brian	G. P. Nevitt, 249 Park Street, New Haven, Conn.

Total 59

Digitized by Google

To be presented at the 328th meeting of the American Institute of Electrical Engineers, Pittsburgh, Pa., January 12, 1917.

Copyright 1917 by A. I. E. E.
(*Subject to final revision for the Transactions.*)

REGENERATIVE BRAKING OF ELECTRIC VEHICLES

BY R. E. HELLMUND

ABSTRACT OF PAPER

This paper discusses the problems met in applying regenerative control to electric railways. In the introductory section the purposes, advantages, requirements and disadvantages of regenerative control are pointed out, and then the author takes up the description of various systems. In doing this, special attention is paid to those systems which are well adapted to illustrate some fundamental principle, and to those which are of some practical importance. Other systems are, on account of space limitations, mentioned only briefly, or entirely omitted.

The three-phase system is discussed under the following heads: regeneration near synchronous and above synchronous speeds; line regulation; practical results and safety of operation; influence upon power factor; regeneration at speeds below synchronism.

The phase converter system is next taken up, with a consideration of the requirements of such a system, and practical results attained.

Direct-current systems of regenerative control and their problems are exhaustively discussed, under the following heads: series, shunt, and separately excited generator; classification and description of separately excited systems with generators operated by line voltage; inherently constant excitation; excitation varying with the line voltage; excitation varying with the regenerated current; series-parallel control; capacity of exciter and switches; systems with variable armature voltage; miscellaneous direct-current systems; transmission system and substations.

The next division of the paper deals with alternating-current commutator motor systems, including those with separately excited generators, armature self-excited generators, excitation varying with the regenerated current, and stator self (load)-excited generators, and the subject of commutation is discussed.

The possibilities of regenerative control with a vapor converter system are then analyzed, and the paper ends with a statement of the general conclusions reached.

THE fact that a motor driving an electric vehicle may, under certain conditions, be converted into a generator and that it will as such exert a braking effect upon the vehicle instead of propelling it, was known very soon after the electric propulsion of vehicles was introduced.

This braking effect may be utilized under two conditions: first, when the vehicle is going down hill, for the purpose of avoiding undesirable acceleration, due to gravity, and conse-

Manuscript of this paper was received July 23, 1916.

Digitized by Google

quent high speeds; second, after a vehicle has reached a certain speed and it is desirable to reduce this speed to a lower speed or to standstill.

The electric energy generated while braking the vehicle in this manner may be disposed of in two ways: first, it may be used up in resistances mounted on the vehicle, in which case it is customary to speak of dynamic braking; second, it may be returned to the power supply system, in which case it is customary to speak of regenerative braking. A combination of the two cases is, of course, possible and may be found advantageous in certain applications. Since in any of these cases dynamic braking takes place, it would be better to use the terms:

1. Resistance braking.
2. Regenerative braking.
3. Combined resistance and regenerative braking.

This paper deals with regenerative braking in particular.

Common to all three cases of electrodynamic braking, are the following advantages over purely mechanical braking:

1. Reduced wear of mechanical braking devices, which, in the case of electric railways, usually results in reduced maintenance cost for wheels and brake shoes.

2. Greater ease and safety in handling the vehicle during the braking period under certain conditions, which results, especially in handling heavy freight trains, in reduced maintenance of couplings and other parts of the cars.

3. Higher permissible average speed in descending grades in certain applications. The braking effect with air brakes cannot be kept constant, so that speed variations will result, when going down grade. Due to these variations, the average speed is appreciably below the maximum safe speed. With electrodynamic braking without the assistance of air brakes, much closer speed control is possible, so that the average speed can be held much closer to the maximum permissible speed.

4. Increased safety by elimination or at least reduction of tire heating caused by brake shoe friction and resulting in loose tires and accidents.

Regenerative braking has the further marked advantages namely:

5. Power economy which amounts in many cases to a saving of 15 per cent or more in the total power consumption.

6. In connection with subways where generation of heat in the tunnels is very objectionable, regeneration is very advan-

Digitized by Google

tageous, as it permits the elimination of an appreciable part of the heat now generated by the mechanical braking system.

It may safely be stated that wherever it seems worth while, the above advantages may be secured in the present state of the art, both on running down grades and during retardation, with any of the systems or types of motors which are now used for the operation of electric vehicles, although commercial systems have been developed, up to the present, for only a few cases.

The requirements necessary to accomplish these results are as follows, and are either partly or in their entirety, dependent upon the system, service conditions, etc.

1. Increased current capacity of the main motors and such transforming or converting apparatus as may be located on the vehicle for the purpose of converting power for the main motors. This is evident because the braking current flowing in the motor, etc., naturally raises the r. m. s. or heating currents. This increase may be appreciable when regeneration is used for stopping trains in local passenger traffic, while it may be rather small in the case of freight locomotives descending grades.

Increased current capacity necessitates, in turn, either increased dimensions of all apparatus affected thereby, or increased ventilation, which may at times be attained by increased capacity of existing ventilating equipments, or by introducing additional ventilating equipment. Where the motors are not loaded to their full capacity for propelling purposes, these requirements may, of course, not exist.

2. Adaptation of the motor bearings and other mechanical parts to regenerative operation, where necessary.

3. Additional equipment on the vehicle for the purpose of controlling and safeguarding the regenerative operation and to give, where necessary, the desirable regenerating characteristic to the motors.

4. Additional equipment in the generating or transforming stations for the purpose of controlling the operation in connection with special conditions brought about by regenerative braking.

5. Adjustment of the system wherever necessary due to the increased tendency towards voltage variation introduced by regenerative braking.

6. Modification of train dispatching so as always to have

Digitized by Google

a load on the line utilizing the regenerated current, in cases where maximum economy in power consumption is of prime importance.

The fulfilment of these requirements as far as they exist in the various systems introduces the following disadvantages of some importance, which have to be compared with the advantages previously enumerated:

1. Increased weight of vehicle equipment, necessitating, sometimes, increased weight of the mechanical vehicle parts.

2. Increased first cost of vehicle equipment, necessitating, sometimes, increased first cost of the vehicle parts.

3. Increased cost of maintenance of the vehicle equipment.

4. Increased complication, and consequent reduced reliability of operation, of the equipment. This will under certain conditions, of course, also impair the safety with which the vehicle may be operated.

5. Increased complication and consequent reduced reliability of the power house, substations and line protecting apparatus. (While some additional complication may be required in the generating and transmitting system, due to the addition of certain controlling apparatus, the weight and cost of the same is usually so low that it is of no practical importance and usually more than outweighed by the gains made in the reduction in size of apparatus made possible by the reduced power requirements).

6. Increased first cost for copper in the transmission system, or for introduction of other means, to compensate, where necessary, for the increased tendency towards voltage variation, whensoever such tendency exists.

The relative importance of the various advantages and disadvantages given above depends, of course, to a large extent upon the individual system applied and upon service conditions. It is evident, for instance, that the importance of power economy depends largely upon the cost of power as part of the total operating expense, and that the advantage of power economy may be entirely eliminated where water power is available in abundance. The latter condition is, of course, as a rule only temporary, because it is to be expected in practically all cases that any such abundance will in time be eliminated by an increased market for electric power.

While the disadvantages, and their importance, vary also in each case, a number of facts apply pretty generally to all

Digitized by Google

systems, and under most service conditions. It is a fact, for instance, that most of the disadvantages enumerated are not of very great practical importance in most cases where conditions are such that the saving in power consumption, made possible by regeneration, is appreciable, say 10 to 15 per cent, or more, or where an equivalent saving or gain is brought about in the maintenance of brake shoes, wheels, increased operating speeds, or the like.

The increased weight of the vehicle equipment and of the vehicle is usually disadvantageous only in so far as it tends to increase the power consumption during acceleration and running. In all but exceptional cases, this increase in power consumption is, however, smaller than the saving made possible by regenerative control, and in many cases it amounts to only a very small percentage of the same. Therefore, the increased weight does not really mean a disadvantage, but merely reduces the advantage of regenerative braking by a certain, and often very small, amount. There are, of course, cases of locomotives where the maximum permissible weight on the drivers is the limiting feature of the design, and any increase of weight may be quite a handicap in such cases.

Similar conditions apply to the increased first cost of the vehicle equipment and the interest and depreciation charges connected therewith. The latter represent again in many cases only a very small percentage of the saving made possible by regenerative control.

In some cases of old equipment where the main motors cannot be readily increased in capacity to take care of the regeneration, or where the mechanical parts, like the bearings, do not operate properly with regeneration, also where extensive changes in the generating and transmission system are necessary, the first cost for introducing regeneration may, of course, make the change prohibitive.

The increased cost of maintenance is in connection with many of the systems not very large, and of no practical importance, as it represents a very small percentage of the saving in power consumption brought about with regenerative control.

The additional complication in the power house or transmission system is also rather small and usually consists, where at all necessary, only in some automatic means for dissipating whatever small amount of energy may at times be regenerated in excess of the energy required for propelling the other vehicles and other loads on the system.

Digitized by Google

The disadvantages resulting from the increased tendency towards voltage variation which may be introduced by regeneration depends largely upon the individual case. In a system where a large number of individual vehicles is operated at all times, as in surface lines, elevated and subway lines in the center of large cities, there will practically always be a large demand for the regenerative current by other vehicles and the result will be not only that the average power taken from the power house is reduced, but also that the maximum demand, and with it, the maximum voltage drop is reduced. In such cases there is, of course, no disadvantage on this score.

On the other hand, there are certain systems where so few trains or vehicles are on the line that it may happen that, at the time of maximum demand for propelling, none of the vehicles is regenerating and that, consequently, no reduction of the maximum power demand, and therefore, no reduction of maximum drop, is accomplished. At other times it may happen that on a certain line one or more vehicles are heavily regenerating while no power, or only a small amount of power, is being drawn from the line. In such a case the voltage drop will, of course, be negative. In other words, there is a voltage rise over the no-load voltage, bringing about an increased total voltage variation.

In many cases such an increase in voltage variation is of no practical importance. In other cases, where the car lighting system is dependent upon the line voltage, or where the main motors, auxiliary motors or generating apparatus are sensitive to voltage rises, the increased voltage variation may require some compensating means. In cases where the car lighting system is affected, it may be found desirable to make it independent of the line voltage by installing special car lighting apparatus. Usually, however, it will be found best to compensate for the increased tendency towards voltage variation by a slight increase in line copper, etc. In certain exceptional cases this might prove to be an item of no small importance against the introduction of regenerative control, on account of first cost. Since the increased line capacity tends, however, to improve the efficiency of the system, the first cost may, even in such cases, be largely compensated by reduced losses in the line The cases in which the considerations of line regulation are of very great importance are rather rare; and in most cases of the present large properties which, as a matter of course, are

Digitized by Google

the first ones to consider regenerative control, this disadvantage either will not exist or will be of comparatively little importance.

In view of the above, and in view of the fact that great efforts have been made to reduce power consumption by other means, like reduction of equipment and car weight, field control, coasting clocks, etc., it is rather surprising that regenerative control has not been used to a greater extent in the past. The only reason for this could be that the increased complication and consequent reduced reliability were considered as a sufficient disadvantage to outweigh the advantages. As long as the various types of controlling and protecting apparatus, as well as the operating characteristics of certain motors during regeneration, had not been developed to such a high degree of reliability as has been attained in many of the up-to-date apparatus and systems, this was undoubtedly a very sound and sufficient reason. With the present advanced state and knowledge of the art, however, this condition has changed, and although some difficulties have to be overcome with the various systems, there is no doubt but that the requirements for reliability and safety can be successfully met, in spite of some additional complication necessary, to a larger or smaller degree, in the various cases. For this reason the subject of regeneration is well worth serious consideration, and the brief outline of the various possible systems given in this paper may be of interest. As a matter of course, the development along these lines will, in the future, as in the past, follow the path of least resistance and the systems requiring the least complication and interfering the least with the reliability of equipment for propelling purposes will be introduced first.

In describing the various systems of regenerative braking, special attention has been paid to those which are adapted for demonstrating some fundamental principle, or to those which are especially important and promising with regard to practical application; many other systems are by necessity mentioned very briefly, or entirely omitted.

Three-Phase System

It is a well-known fact that any induction motor if driven by mechanical torque above synchronous speed will be converted into a generator without any change in connections and without requiring any manipulation of the master controller. In other words, a vehicle of a three-phase system when going down-

Digitized by Google

hill will automatically give regeneration as long as the motors are connected to the line, whether such a condition is desired or not—assuming, of course, that the grade is steep enough to accelerate the train and that the accelerating tractive effort is not used up by the mechanical brakes or other losses. The usual practise is to start the vehicle in the normal way and leave the power on, when going down grade; but even if the power has been disconnected and regeneration is desired, power connections can be re-established in the same manner as when the motors are starting, because the introduction and gradual elimination of the rotor rheostat will avoid excessive overloads over wide ranges of speed conditions. Regeneration in this case, therefore, does not introduce any complication whatsoever on the vehicle and in order to obtain satisfactory results, it is only necessary to equip the vehicle with motors and transformer, if the latter be used, of sufficient capacity to take care of the regenerative currents. Wherever there is danger of the regenerative power at times exceeding the power demand, resistance, preferably of the water resistance type, has to be provided in the power house, with some automatic means to connect it in the circuit whenever a surplus of power is to be taken care of. All alternating-current transmitting, transforming or converting apparatus will act as well under regenerative conditions as otherwise. Only in case of rotating converting apparatus being used in the system, possibly in the form of frequency changers, a certain amount of danger is introduced by the possibility of such apparatus over-speeding when the main power supply is interrupted for some reason or other, and a train going down-hill furnishes power to the converting apparatus. In such a case, the train may, of course, accelerate and increase with its own speed the speed of the converter. This condition can, however, be very easily taken care of by over-speed relays on the converter, the same as is now being done for similar reasons in connection with synchronous converters and the like.

The proper balance of the regenerative load between the different motors of a vehicle in case of slight variation in wheel diameter can be taken care of by the means provided for the same purpose during motoring.

Some additional slight complications may be introduced whenever in some exceptional cases a locomotive is required as part of its regular service to take a train down-hill with tractive effort in excess of that given by the slipping point of the wheels

Digitized by Google

of the locomotive. In such cases it is necessary to use air brakes in the train and to work them in conjunction with the regeneration of the engine. Since it is at present considered very difficult or almost impossible to exert a uniform torque with the air brakes, the use of the air brakes means, as previously mentioned, a necessity for varying the speed of the train about 5 to 10 mi. per hr. (about 8 to 16 km. per hr.) while descending a grade. In order to enable the inherently constant-speed induction motor to follow such speed variations, while at the same time regenerating, it is necessary to introduce a variable resistance into the rotor circuit which in turn permits speed variations from synchronous speed to speeds about 5 to 10 mi. per hr. higher. The resistance may, in this case, be regulated either automatically, which, of course, means some complication, or manually, which, in turn, would require a certain skill on the part of the operator. It is further a fact in this case that a part of the regenerated energy when running above synchronous speed cannot be returned to the line, but has to be dissipated in a resistance, the amount of this energy, in per cent of the available mechanical energy, being approximately in proportion to the actual speed obtained minus the synchronous speed, the difference to be divided by the actual speed. While the loss of energy in itself may not be of great importance, it is at times a serious problem to get a big enough rheostat for successfully dissipating such energy, especially since the necessity for doing so usually arises only in connection with very heavy railway work. In order to demonstrate the possibilities of regenerative braking with speeds varying above synchronism, Fig. 1 is given, showing speed-torque curves of a typical induction motor with different resistances in the secondary; Fig. 2 also gives the approximate percentage of regenerated power which has to be dissipated and wasted in resistances on the vehicle. It will be seen that all curves are in very close agreement with curve A, which is plotted in accordance with the approximate rule given above for the losses.

The conditions just described also apply, of course, if operation at speeds above synchronous speed is desirable or necessary for any other reason. It may, for instance, be desirable in certain cases to take light loads down-hill at over-synchronous speed by using resistance in the secondary; the only limitation in doing this is the limit imposed by the capacity of the secondary rheostat, and the limiting safe speeds from a mechanical point of view.

Digitized by Google

The increased tendency towards voltage variations with regeneration is of no great practical importance in connection with polyphase systems, because all parts of the system can easily stand a slight voltage increase for the short interval of time during which it usually exists. As previously mentioned, the higher voltage increases the torque of the motors, and, therefore, does not impair the reliability of service. The high voltage may at times unfavorably affect the power factor and the losses in the system, but in so far as it only exists at times of

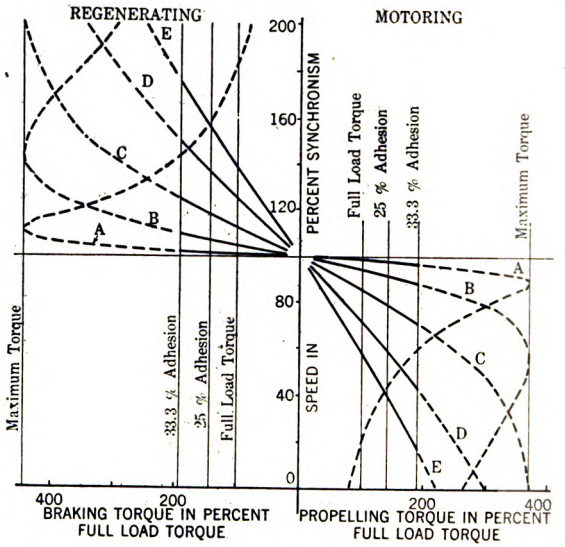


FIG. 1—RAILWAY INDUCTION MOTOR CHARACTERISTICS

Curve *A* = Rotor short-circuited.
" *B* = Rheostat resistance = 3 × rotor resistance.
" *C* = " " = 9 × " "
" *D* = " " = 19 × " "
" *E* = " " = 29 × " "

light load, this is of no great consequence. It is, moreover, to be considered in this connection that with the high line voltages possible in alternating-current systems, the line regulation may be kept fairly good without undue amounts of copper in the system. The fact that regeneration with induction motors does not decrease the wattless currents, but rather increases them, will, to a large extent, eliminate any tendency towards increased voltage variations.

The great ease and simplicity with which regeneration can be obtained under most conditions with polyphase vehicles

Digitized by Google

for the purpose of braking down-hill is undoubtedly the reason why such regenerative braking was introduced practically as soon as three-phase power was used for railway purposes. The results obtained with regenerative braking on the three-phase electrifications in Europe for the last 12 to 16 years have been exceedingly satisfactory and beneficial, all the advantages of reduced wear and tear of mechanical brakes and other parts, of economy in power consumption, and increased operating speeds on down grades, having been realized to a large extent.

The degree of safety in operating a vehicle or, especially,

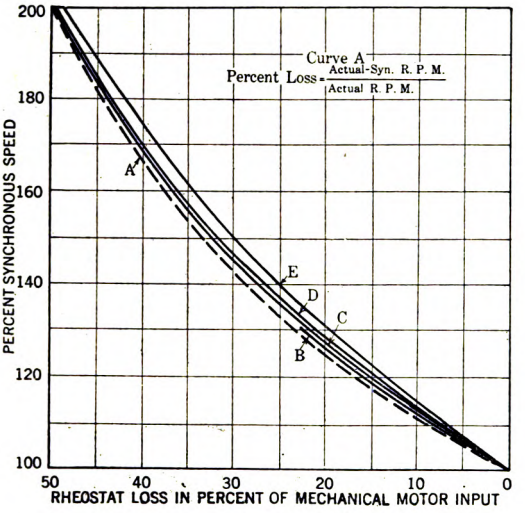


FIG. 2—RHEOSTAT LOSSES, REGENERATION

Curve *B* = Per cent rheostat loss at 75 % full-load torque.
" *C* = " " " " " " 150 " " " "
" *D* = " " " " " " 225 " " " "
" *E* = " " " " " " 340 " " " "

heavy trains down-hill with regenerating induction motors with short-circuited secondaries is almost perfect, and limited only in a few respects. The vehicle speed is kept practically constant with very wide ranges of load and an interrruption of the braking tractive effort takes place only in case the power supply is interrupted, or possibly if some of the main driving elements of the vehicle are seriously damaged. This is usually at once indicated to the engineer by the meters in front of him, and in so far as the regeneration has definitely kept the vehicle down to safe speeds previous to the loss of power, or the like, it has in practise always been found very easy to get the train or the vehicle

Digitized by Google

under the control of the air brakes before unsafe speeds were reached. In the case of especially steep grades or other severe conditions, it is, of course, quite feasible to provide automatic means for putting on the mechanical brakes in case of emergency. The maximum braking torques which can be exerted are usually limited only by the slipping point of the wheels, since it is as a rule easily possible to keep the pull-out torque of the motors a safe amount above this point. While in motoring the pull-out torque may be reduced by excessive voltage drops, heavy regenerative braking will rather tend to bring about a rise in voltage with consequent increase in the maximum braking torque, which is, even with equal voltage, larger than the motor torque (see Fig. 1). Slipping of the wheels, where it is liable to occur, can be avoided by introducing automatic current-limiting or torque-limiting devices which prevent an increase in braking torque above the slipping point, for instance, by introducing a resistance into the motor secondary, thereby limiting the load.

There is one point worth mentioning in connection with regenerating induction motors, which is often construed to be a disadvantage, whereas it actually is not a disadvantage at all, but merely reduces the advantage which may be secured from regeneration. A system with regenerating induction motors is liable to show a very low power factor, due to the fact that induction motors while regenerating actual power take wattless current from the line, unless power factor compensating means are used; in other words, they increase the total wattless current and decrease the total watt current, which has, of course, a bad influence on the power factor. It should not be forgotten, however, in this connection, that the term "power factor" is very apt to be misleading in a case like this. Even if we assume, for instance, that the increase of wattless current as compared with the decrease of watt current is such that the total current remains unchanged, we have, of course, no saving in r. m. s. current drawn from the line, and also, a very much lower power factor. Nevertheless, we have reduced the actual power consumption, which in turn, means a saving in the coal pile of the power house. Moreover, it is a fact that the larger systems usually have synchronous converters, phase advancers, or other means for taking care of the power factor, and a slight increase of this apparatus will usually take care of the additional wattless current introduced by regeneration.

While the three-phase system (and its closely related single-

Digitized by Google

phase system with phase converters on the locomotive) is undoubtedly the system best adapted for effecting the braking near synchronous speeds on down grades for the purpose of avoiding increased speeds, the possibilities for reducing the speed of a vehicle from its normal operating speed by regenerative braking are either very limited in scope with induction motors, or the equipments are, at present, at least, so cumbersome or complicated that their application in practise does not seem to be very likely in the near future.

If the vehicle is arranged so that two or more economical operating speeds may be obtained either by employing two-speed induction motors or by connecting motors in cascade, or both, it is possible to effect regenerative braking in bringing the vehicle speed from the higher speeds down to near the lowest synchronous or economical operating speeds. This can be accomplished by connecting the motors for one of the lower operating speeds and properly manipulating the resistance in the secondary. If done manually, this requires a certain amount of skill on the part of the operator, and if done automatically it means, of course, complication. It has also been observed that under certain conditions such operation is liable to cause over-voltages in the motor secondary. For these reasons, regenerative braking has not been utilized to a very great extent for this purpose.

Regenerative braking with induction motors over a wide range of speeds and down to zero speed may be accomplished by applying a so-called regulating commutating machine, working in conjunction with the secondary of the induction motor. Such a machine is, however, with the present known systems, so large, and, on account of many commutator brushes, subject to such high maintenance cost that its use would, to a large extent, counterbalance the additional saving made possible by braking at lower speeds. It is, however, not at all impossible that as the art advances, developments along this line may make regenerative braking below synchronous speed feasible in practise. Whenever this is the case, the present speed limitations of the induction motor would at the same time be eliminated, or minimized, and acceleration without rheostatic losses, with attendant saving in power, would be made possible at the same time.

Phase Converter System

The conditions prevailing with a phase converter system employing a single-phase line, a phase converter locomotive

Digitized by Google

and induction motors for propelling, are, with regard to regenerative braking, practically the same as with the three-phase system. This means that regenerative braking on down grades can be accomplished with the same ease and safety and without requiring complications of any practical importance, while the use of regeneration for retardation is at present either limited in scope or complicated.

The only slight differences between the phase converter system and the polyphase system are:

1. The system employs on the vehicle a rotary converting device, which, if of the synchronous type, requires for its protection a standard over-speed relay.

2. The use of regenerative control introduces an increased tendency towards unbalancing of the three phases of the converter system, and may require a small extension of the balancing devices—that is, possibly an extra position of the balancing control lever and one or two extra switches. The safety of operation is, however, in no way impaired by this because, even if the balancing switch is not operated correctly, the motors will perform properly and the only result will be an increase in motor heating.

3. Since the vehicle, if equipped with a synchronous phase converter, going down grade represents in itself an independent generator station, this must be taken into account when laying out the overload and short-circuit protection of the system.

In view of the simplicity of the system, it was only natural that regenerative control was utilized as soon as the phase converter system was applied in practise; in fact, the ease with which regeneration can be used in combination with a converter system was one of the factors in favor of the adoption of this system for the Norfolk and Western Railway. The practical value to the railway company of the regenerative characteristic in operating this mountain grade is far beyond expectations and has been a surprise to the railway operators. The economies accomplished in power consumption, reduced wear of tires and brake shoes, etc., are very appreciable, and not only can the trains be handled much more easily and at higher average speeds down grade than with air brakes, but also the reliability of the system as a whole has been greatly improved by the regenerative feature.

Direct-Current System

The present-day direct-current railway motor lends itself less readily to regeneration than the polyphase induction motor.

Digitized by Google

The series motor, which has generally been introduced in railway work on account of its superiority for propelling purposes over other types of direct-current motors, cannot as such be readily used as a generator under railway conditions. While it is true that a series motor can be made to act as a generator, if its fields are reversed, it is very unstable. In order to make a series motor regenerate, it would first have to be connected across a resistance to make it pick up and after its voltage has reached a value higher than the line voltage, it could be connected to the line and made to furnish regenerated current. Assuming, however, that the line voltage suddenly drops, as is common in railway practise, the regenerated current would, of course, increase; this, in turn, would increase the field strength, which would again tend to increase the regenerated current. This cumulative effect would quickly and frequently lead to excessive overloads on the entire equipment. Assuming, on the other hand, that the line voltage suddenly rises after the motor has started to regenerate, this will bring about a decrease in regenerated current. This, in turn, decreases the field excitation and produces consequent further decrease in current down to zero; further, since the field and counter-voltage would be zero with zero current, excessive currents in the opposite direction would build up, which are liable to exceed the most severe short circuits, because after the current once reverses, the motor sets up a field and a voltage adding to that of the line. The processes just described happen so quickly, on account of their accumulative nature, that it is practically impossible to build relays or other safeguarding devices which act rapidly enough to be effective.

In order to effect regenerative control with direct current it is, therefore, necessary either to apply altogether straight vehicle shunt or compound motors, which would mean giving up many of the essential advantages of the direct-current series motors for railway purposes, or to convert the series motor temporarily into a machine of different characteristics while regenerating.

Since the field coils of a series motor are wound with only a few heavy turns, they cannot very readily be connected as shunt coils across the line voltage, and it would be necessary, in order to obtain shunt excitation, to connect considerable resistance in series with the field. This resistance would consume a very large part of the regenerated energy, with little or no consequent saving in energy. These conditions can be somewhat improved

Digitized by Google

where several motors are available by connecting all motor fields in series and the armatures in parallel, but even then, only a relatively small part of the regenerated energy remains to be sent into the line. Such a system will, therefore, only be applied in exceptional cases where power consumption is of relatively small importance and the principal purpose is to effect electrodynamic braking with the least amount of complication, in order to secure advantages other than power economy.

A system of that kind is quite safe and reliable in operation. A sudden change in line voltage will tend to change the regenerated current, but such a change is counterbalanced by the fact that the excitation changes at the same time and causes a change in the counter e. m. f. which reduces the change in regenerated current. This process is fairly quick-acting because the time element of the field current is rather small on account of the large amount of resistance connected in series with inductance of the field. Excessive regenerated currents are thereby avoided automatically. Only when the motors are highly saturated an increase of field strength is, of course, not possible, and larger regenerative currents may then occur. In view of the small field of practical application for this system, a detail discussion of it may be omitted.

Since generators of the straight series, shunt or compound type cannot be readily made out of the standard up-to-date railway motor and used to good advantage, motors with separate excitation are the next and most promising possibility for successful regeneration, although the addition of a separate source of current for the excitation introduces an undesirable complication.

The various connections, methods of excitation and consequent characteristics of the generators which are possible in connection with separate excitation are very numerous. Therefore only a few typical cases can be described in this paper. Before doing this, some of the more important problems to be met in connection with the separate exciter method of regeneration may be discussed.

First. One of the principal conditions to be met in connection with direct-current generation is, as previously intimated, to avoid excessive armature currents, especially at higher speeds. While with any type of motor excessive overloads are undesirable for any length of time, it is a fact that overloads of short duration are not so very dangerous in connection with induction motors,

Digitized by Google

for instance, because the mechanical parts of freight locomotives on which induction motors are being used are in most cases designed to stand stresses up to the slipping point of the wheel and the wheel slippage acts as a mechanical fuse against much higher stresses; on the other hand, overloads of very short duration are not very serious from a heating point of view. With direct-current motors running as generators, high armature currents, even though of very short duration, introduce an additional difficulty because they are liable to lead to flashing of the motors. It is a well-known fact that flashing of motors is caused by high voltages between the commutator segments. The voltage between segments, in turn, depends upon a great many details of design, but the maximum voltage is largely determined by the armature distortion. With a series motor, in which the field strength and the armature current are always proportional to each other, the armature distortion as a rule does not increase, under normal conditions of operation, with increased load, and has often even a tendency to decrease with heavy loads, on account of saturation. With a separately excited generator, conditions are altogether different. When running at very high speeds with a fixed motor voltage, for instance, the field strength must be, by necessity, very low. This is evident because the voltage induced must be about the same as the impressed voltage, and since the induced voltage is the product of speed and field strength, high speed means, necessarily, low field strength.

Since, on the other hand, the braking torque which the generator can exert is proportional to the product of armature current and field strength, it is evident that at high speeds and consequent weak field, relatively large armature currents are required in order to exert an appreciable braking torque under normal operating conditions. This will in itself tend to increase the armature field distortion materially. This latter condition is, of course, only brought about by the fact that the present-day requirements for retardation are more exacting than for motoring. During motoring it is customary to have a certain maximum rate of acceleration until the motor curve is reached and to tolerate thereafter a decreasing rate of acceleration which is naturally obtained while the motor field, and with it the armature current, decreases and while the speed increases. In certain cases, it may be quite possible to follow the reverse process during braking, that is, start in with small field current and smaller armature

Digitized by Google

current and consequent slow rate of retardation, and increase all the values while the speed decreases. Insofar, however, as the mechanical brakes used at present are able to exert the maximum permissible braking torque at the higher speeds, which, in turn, permits higher schedule speeds with the same maximum speeds, regenerative braking will not be able to compete unless at least similar conditions can be obtained. Therefore, it will be necessary in most cases to work with relatively large armature current, unless provision is made to change the motor voltage during regeneration, thereby permitting the use of stronger fields at high speeds. This solution of the problem could be accomplished in two ways: first, the regenerative voltage could be raised above the line voltage by some means or other, as will be discussed later on and shown to be rather undesirable; second, arrangements could be made to keep the voltage during motoring below the line voltage and regenerate at full line voltage. This could be accomplished by designing the motors to stand full line voltage but to operate, while motoring, with two motors connected in series, with one-half the voltage in each motor. Under special conditions with special motor designs, such a solution may be quite feasible. As a rule, it would be more desirable, however, to use standard motors even though this means the use of heavy armature currents for high speeds, and with it, large field distortion. It is fortunate in this connection that this undesirable feature and its consequent danger are to a large extent eliminated by the fact that when regenerating, the distortions are such that the highest voltages between segments occur at a point a considerable distance away from the toe of the brushes, so that an arc is not as liable to be drawn over from the brush as would be the case if the highest voltages were near the toe of the brush under otherwise equal conditions. It is, therefore, permissible to work with considerably higher maximum voltages and, therefore, greater distortion when regenerating. Practical conditions are nevertheless such that, in view of the high field distortions necessary for normal operation, further increases on account of sudden rises of regenerative currents in the armature are very liable to lead to flashing.

There are two principal causes for sudden increases of regenerated current.

(a) The first of them is the taking of steps in the control. If, for instance, the field excitation should be suddenly raised

Digitized by Google

by a large amount, the regenerated currents would take undue proportions. This, of course, can be avoided by making the control steps small enough by providing a sufficiently large number of them. In order to avoid the expense and complication incident to a large number of steps, it is desirable to have a regenerative machine characteristic which avoids large changes of regenerative current even though the number of steps is small.

(b) The second and much more important cause of sudden changes in regenerative current is as previously pointed out in connection with the discussion of the series generator, sudden changes in the line voltage. While it is not altogether impossible to prevent sudden increases of load due to this cause by having quick acting relays, causing changes in the excitation of the generators to take care of the changed conditions, it is at least very difficult with some systems to get such relay devices and switching operations quick and reliable enough to avoid flashing. For this reason, it is very desirable, and for a reliable system even necessary, to have such regenerative characteristics as inherently to avoid excessive armature currents. In this connection it is not only necessary to have such an inherent characteristic, but it is also important that the time element for effecting changes in the generator conditions be exceedingly small.

Second. Another feature to be considered in connection with regenerative control is the ease with which the motor can be connected to the line after it has been disconnected and when regenerative control is desirable. In order to make such connections with some types of separately excited motors, it is necessary to have the regenerative voltage about equal to the line voltage before such connection can be made. As a matter of course, it is impossible to follow, in operating a vehicle, the power house practise of balancing the voltages by means of a voltmeter before connecting the generators to the line. Therefore, automatic means have to be provided for this purpose. Such automatic means, in turn, require relays which have to be very exact unless the system used is inherently such as not to require a very careful balancing of the voltages before the connections are made. This point is quite important in the choice of the proper system.

Third. Another point of importance in connection with regeneration is that the regenerative load be properly distributed among the various motors of the vehicle. It is evident, for

Digitized by Google

instance, that a slight difference in the air gap of the motors or a difference in the wheel diameters will cause a very uneven distribution of load if the armatures of several motors were to be simply connected in parallel. A good system of regeneration, therefore, has to have means of balancing the load fairly well between the various motors under practical conditions. While such balancing may of course be effected by relays which operate regulating switching devices, it is again preferable to have a system in which the load balancing effect is, at least to some extent, inherently given by the generator characteristics.

Fourth. Another condition to be fulfilled is that the braking effect of the vehicle shall not materially decrease with increased vehicle speed, or materially increase with decreased speed, at least not so suddenly that the relays of the automatic control, or the operator in case of manual control, cannot follow such changes quickly enough. Sudden large changes of braking torque should also be avoided in case of changes in the line voltage conditions.

Let us assume, for instance, that the speed of a train is to be reduced by regeneration, and a certain maximum permissible braking torque has been established. If it happens in this case that the braking torque suddenly increases, either on account of changed line conditions or the generator having a characteristic so that the torque increases while the speed decreases, this will lead either to slippage of the wheels or to an undue rate of retardation resulting in bumping of cars, inconvenience to passengers, etc., all of which should be avoided.

Another case to be considered in this connection is that of a heavy train going down-hill. Let us assume that such a train gets on a steeper grade and consequently speeds up to some extent. If in this case the generator characteristics should be such as to give a decreased torque with increased speed, the train speed may increase unduly on account of the combined effect of the increased grade and the decreased torque before the engineer has a chance to readjust the control or the air brakes, or both.

Unfortunately, the condition that the braking torque should preferably decrease with decreased speed, and vice versa, cannot be combined with a machine characteristic best suited to avoid armature distortion and motor flashing.

The ideal characteristic for avoiding motor flashing is one with which the ratio of armature ampere-turns to the field

Digitized by Google

ampere-turns remains constant with changes in speed. Such a characteristic can be approached in practise, as will be shown later on, and is represented by curve *A* in Fig. 3A. It will be seen that this curve is shown as a straight vertical line down to a certain point.

The armature current curve corresponding to curve *A* is shown by curve *B*. It will be seen that the upper part of this curve shows a rapidly decreasing armature current with increased speed. This is due to the fact that, as previously pointed out, the field strength has to decrease with increased speed, which in turn means that the field ampere-turns have to be decreased. With our present assumption, this means that the armature current must also decrease with increased speed.

Curve *C* shows the torque obtained under the same conditions. Since the torque is the product of field strength and armature current, both of which decrease with the speed in the present case, it is evident that this curve must decrease very rapidly with increased speed, except on the part of it which is turned around by the effect of saturation. Fig. 3A demonstrates very plainly that the characteristic which is ideal for flashing conditions is highly undesirable, for the reasons previously pointed out, in connection with the most desirable torque characteristics.

The next best possible characteristic for flashing which might be considered is one with which the armature current remains practically constant over a wide range of speed, as shown by curve *B* in Fig. 3B. Curve *A* in the same figure shows the corresponding curve for the ratio of armature turns to field ampere-turns.

Curve *C* shows the corresponding torque curve, which still shows a considerable tendency for decreased torque with increased speed. It is evident that such tendency must exist since, as we know, the field strength must decrease with increased speed, which, with constant armature current, means also decreased torque.

The extreme opposite to the characteristic assumed in Fig. 3A is shown by Fig. 3c. The torque curve *C* shows a very rapid increase of torque with increased speed. Such a torque curve affords maximum safety for the vehicle when going down-hill, because any tendency towards increased speed will be counteracted by a rapidly increasing braking torque. For retardation of the vehicle, such a curve would, of course, require a very large number of small steps in the control in order to avoid

Digitized by Google

excessive variations in the braking torque when going from one step to another.

Curve *B* shows the corresponding armature current curve and curve *A* the corresponding curve for the ratio of ampere-turns. It will be seen that the latter curve shows an excessive increase

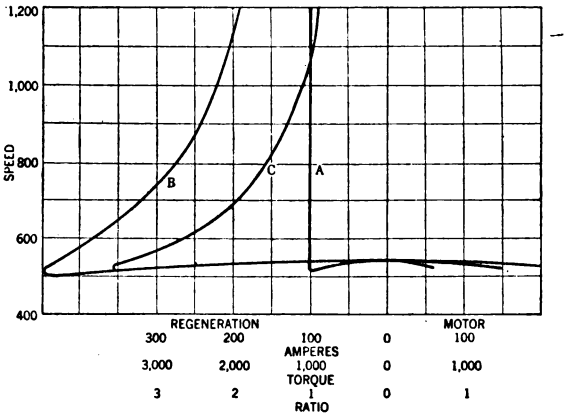


FIG. 3A

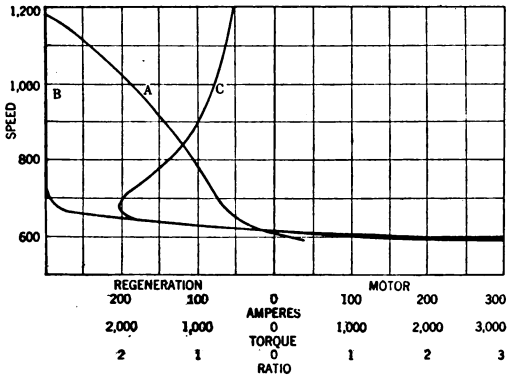


FIG. 3B

A = Ratio of Armature to Field Current
B = Armature Current
C = Torque

with increased speed and is very undesirable with regard to flashing.

The natural conclusion to be drawn from the previous figures is that in practise a compromise between these extremes is the only workable solution. Fig. 3D shows characteristics for the

Digitized by Google

ratio of ampere-turns, current and torque which will be suitable for the average conditions in practise. The steepness of the current curve will, of course, vary, depending upon the service conditions, the inherent sensitiveness of the motor to flashing and a number of other considerations. As a rule it will be desirable to have the curve somewhat steeper for the higher speed notches than for the lower speed notches. It has been pointed

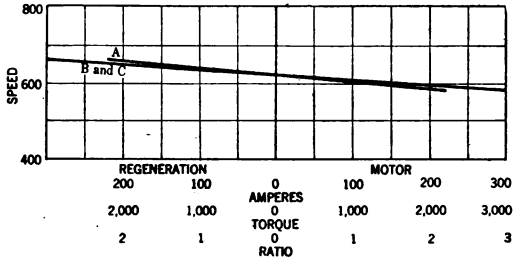


FIG. 3C

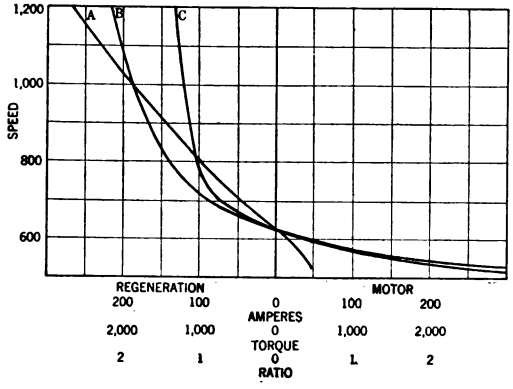


FIG. 3D

A = Ratio of Armature to Field Current
B = Armature Current
C = Torque

out before, that in order to obtain an appreciable torque with the weak field necessary for the higher speeds, large armature currents and high ratios of armature to field ampere-turns are necessary; therefore, it is in this case especially desirable to have a steep current curve, avoiding further increase of armature current. With low speeds, on the other hand, we have, by necessity, strong fields and weak armature currents for similar

Digitized by Google

torques, and, therefore, a favorable ratio of armature to field ampere-turns. A certain increase of armature current is, therefore, permissible and a rather flat current curve may be chosen.

While the curves of Fig. 3 show the characteristics with regard to the speed, it will be found that the same conclusions will be reached if current changes caused by fluctuations in line voltage are taken into consideration. The requirements for a satisfactory speed-torque curve will also in these cases limit the use of the most desirable characteristic for avoiding overloads and flashing.

A characteristic showing gradually decreasing torque with decreasing speed should also prove to be rather advantageous where it is necessary in the case of exceptionally heavy trains to operate air brakes in conjunction with the regenerative braking. If, for instance, the air brakes are put on rather heavily, the train speed will decrease because the air brakes are exerting a heavy retarding force. If the motor characteristic is such as to give a decreased torque at the same time, the total increase of torque is counteracted and further decrease in speed will be prevented. The opposite action will take place and it is even more important when the air brakes release a certain amount. If the vehicle speeds up in this case, the inherently increasing regenerative torque will prevent further increases of speed. It is evident, therefore, that a compound characteristic, as previously discussed in the case of the main generators, will permit operation at a more uniform speed, even when using regenerative braking in conjunction with the air brakes, than would be possible with air brakes alone.

Fifth. Still another point to be considered in connection with the various systems is the danger of over-voltages on the motors in case the power supply should be interrupted for some reason or other. The natural tendency with most systems fulfilling the previous requirements is, in case of power interruption, for the voltage of the generators, being no longer limited by the line voltage, to rise until saturation is reached.

Since railway motors when operating at high speeds as generators are always far from being saturated, it is quite possible to obtain voltage rises of two or three times normal voltage. It is evident that such over-voltages are likely to lead to flashing and even insulation breakdowns. While these over-voltages can, of course, be taken care of by relays causing an interruption

Digitized by Google

of circuits or the like, the inherent characteristics of the system should be such as to introduce a time element sufficient to allow over-voltage relays to act before the over-voltage becomes excessive and dangerous.

Unfortunately, it is also a fact that those systems which are the quickest to act in avoiding excessive armature currents are usually the ones which are most liable to set up over-voltages quickly in case of power interruption when running at high speeds. It is, therefore, again necessary to strike the best compromise.

Sixth. It is finally necessary in connection with regenerative control to pay much attention to the proper characteristics of the auxiliary exciting apparatus, in order to have the system free from troubles. The principal danger in this connection is that the auxiliary exciter set, especially the driving part, is subject to flash-overs unless proper precautions are taken in that direction.

With these considerations in mind, we may now discuss the principal possible characteristics of the source used for the separate excitation and the consequent characteristics of the main generators. When referring in this connection to the characteristic of the source of excitation, etc., the inherent characteristic is meant, it being assumed in all cases that variations of excitation can be, and are, accomplished by changes in the circuit connections, changing of resistances, etc. The following cases for the main field exciting voltage may be considered:

1. The excitation is of practically constant voltage.
2. The excitation voltage varies with the line voltage, either in direct proportion or in some other ratio.
3. The excitation voltage decreases with an increase of regenerative load.
4. The excitation voltage changes with both the line voltage and the regenerative load. A number of different combinations are, of course, possible.

The undesirability of an increase of field excitation with increased regenerative current has been pointed out in connection with the series generator. An inherent increase of excitation voltage with decreased line voltage is undesirable, because a decreasing line voltage inherently means increased regenerative load and this load would of course be further increased, were the excitation raised at the same time.

Digitized by Google

SYMBOLS USED IN CONNECTION DIAGRAMS

A, A_1, A_2	Main machine armature or armatures.
B	Booster armature.
C	Control contacts.
D	Relay.
E	Source of field exciting current.
F, F_1, F_2	Main machine field or fields.
G	Ground connection.
H	Field winding of exciter armature.
I	Inductance.
J	Differential field winding on exciter machine.
K	Differential field winding on motor driving exciter machine.
L	Field winding of motor driving exciter machine.
M	Armature of motor driving exciter machine.
N	Armature of machine driving booster or driven by the booster.
O	Shunt field of booster machine.
P	Shunt field of machine driving booster or driven by the booster.
Q	Series field of machine driving booster or driven by the booster.
R, R_1, R_2, R_3	Resistances.
S	Series field of booster.
S_1, S_2	Switches.
T	Trolley.
T_1	Main transformer winding.
T_2	Auxiliary transformer winding.
U	Auxiliary shunt field on exciter machine.
V	Auxiliary shunt field on booster.
X	Cross field of main machine.
Y	Cross field of exciter machine.
Z	Reverser.
aa	Working brushes of main machine.
bb	Exciter brushes of main machine.

Practically constant excitation, as obtained, for instance, with a battery (see Fig. 4), does not give very desirable characteristics with regard to limiting the armature currents. If, for instance, the line voltage drops suddenly, the regenerative voltage will be much in excess of the line voltage and the only thing inherently counteracting excessive currents is the small resistance in the circuit and possibly a slight voltage reduction

Digitized by Google

in the generator due to the increased armature field distortion. This, however, is not at all sufficient with the large voltage variations common to railway work. Fig. 6 shows test curves, taken on a standard medium size railway motor, clearly demonstrating this point. It will be seen that with a voltage drop of only about 10 per cent, the regenerative current increases

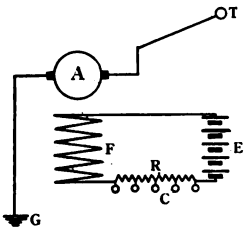


FIG. 4

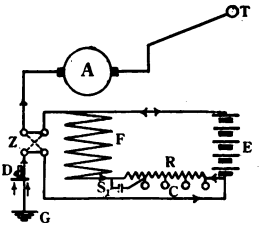


FIG. 5

100 per cent or more, depending upon the load, and the ratio of armature to field current goes up practically in the same ratio. Conditions can of course be improved by introducing a resistance into the circuit.

The only other way in which this shortcoming of the system with constant voltage excitation can be taken care of is by the use of quick-acting controlling devices. The system shown in

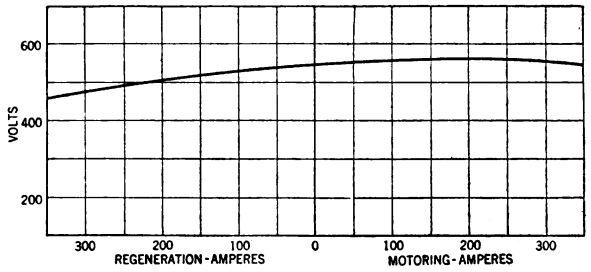


FIG. 6—SPEED CONSTANT; FIELD CONSTANT

Fig. 5 was developed along such lines some years ago and gave quite satisfactory results during an extended testing period. The motor fields were reversed in this case so that the regenerative current assisted in magnetizing the field, while the battery E took only the difference between the regenerative current and the exciting current. The regulation of the system was accomplished by a controller device C, varying part of the resist-

Digitized by Google

ance R. In addition to this, a quick-acting relay D opened the switch S_1 automatically every time the armature current exceeded a certain value, introducing temporarily a part of the resistance into the field circuit. The operation of this relay and switch was found to be somewhat like that of a Tirrill regulator insofar as it very frequently opened and closed the switch S_1, the time of opening usually being only long enough to give the field current a start in the right direction when the armature current exceeded desirable values.

The flat speed characteristic of a system of this kind requires, of course, a relatively large number of notches in the control in order to avoid excessive changes of current and torque while notching up, as is evident from Fig. 7. The necessity for many steps is, however, somewhat reduced by the self-inductive and

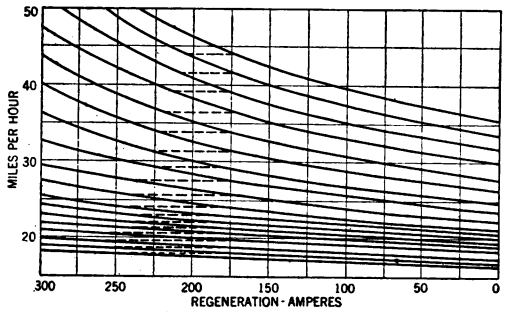


FIG. 7—CONSTANT VOLTS

damping effect of the main motor field, which introduces a time element making the change of the field strength fairly slow, so that the vehicle has a chance to retard somewhat before the new field condition caused by taking a notch in the control has been fully established. This will limit somewhat the current peaks. With the system of Fig. 5, the operation of the relay D and the switch S_1 will also oppose any excessive current peaks during the notching up.

The systems with inherently constant excitation require, of course, fairly close adjustment of voltages before the generator can be connected to the line. Certain limited inaccuracies can be taken care of by the system of Fig. 5 if arrangements are made so that the generator voltage is always larger than the line voltage before the circuit is closed. If then the generator voltage is somewhat too large, tending to give excessive regen-

Digitized by Google

erated currents, the operation of the relay D and the switch S_1 will tend to keep the currents down.

Proper distribution of load between the various motors can, of course, only be taken care of in a system of this kind by individually controlling each motor by means of separate controlling resistances and controlling devices, there being no inherent tendency for balancing the loads.

A system with constant excitation possesses, on the other hand, quite desirable characteristics with regard to some of the other considerations. Any tendency towards increased speed of the vehicle is at once counteracted by a very large increase of torque. Over-voltages can be obtained only after the vehicle speed has increased, and since this requires a certain amount of time, over-voltage relays will have plenty of time to act; as a matter

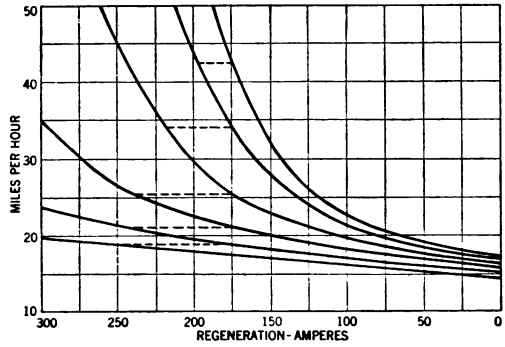


FIG. 8—CONSTANT VOLTS

of fact, this system is one of the safest with regard to over-voltages. The use of a battery as a source of excitation is, although fairly satisfactory, not very desirable, in view of the care and maintenance always incident to a battery.

A system in which the excitation voltage varies in proportion to the line voltage is shown in Fig. 9. A dynamotor merely serves as a transformer for reducing the line voltage to a voltage suitable for the excitation of the motor fields. Therefore this system acts in many respects identically with one having a straight shunt generator. Any increase of line voltage is followed by a proportional increase of excitation voltage. Such an action is ideal, assuming that the change in field follows that of the line voltage quickly enough, and assuming further that the changes in field flux are proportional to the changes in field voltage.

Digitized by Google

These latter conditions are fairly well taken care of in the system of Fig. 9, as long as the main motors are not saturated, and assuming that the dynamotor field flux responds quickly to the changes of its field current. The latter requirement can easily be fulfilled by exciting the dynamotor with a series field only, as shown, avoiding thereby the damping effect of shunt-connected windings, and by making the dynamotor field core laminated, thereby avoiding the damping effects of a solid core.

If the line voltage, under these assumptions, drops suddenly, the counter e.m.f. in the dynamotor will at first be larger than the line voltage. Therefore, the current taken by the dynamotor, and with it the dynamotor field current, will quickly decrease. Since the laminated field will follow the change of its field current, the voltage induced in the secondary armature winding of the dynamotor will quickly readjust itself to be proportional to the line voltage. Although the inductive and damping effects of the main generator fields introduce a certain time element, very excessive increases of regenerative currents will be inherently avoided when running at higher speeds. For lower speeds for which the main generators may be saturated, their fields of course change less than proportionally to a change of field voltage and current. In these cases the field is, however, very strong and undue field distortion will not take place, even though the armature currents may assume rather large proportions, until the control can be readjusted by relays or otherwise. The effect of changing line voltage with this system is shown by the curves in Fig. 10.

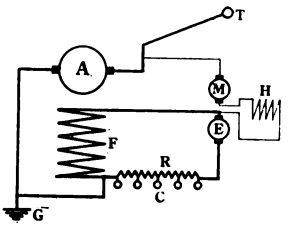


FIG. 9

While, for the above reasons, this system is very satisfactory for taking care of variations in line voltage, it is less so with regard to the steps of the control, the speed-current and speed-torque characteristics being essentially those of a shunt machine, so that in this respect the same conditions apply as in the system of Fig. 5 and as demonstrated in Fig. 7.

Another handicap of this system is that when the motors are connected to the line, excessive currents are liable to be set up unless the voltage balances rather exactly or unless other precautionary steps, like a temporary introduction of a resistance into the circuit, are taken.

Digitized by Google

Proper distribution of the load is not obtained inherently with this system and has to be taken care of by separate regulating rheostats or the like for each generator. The system is, on the other hand, very satisfactory with regard to the safety of the train, because any tendency towards change in speed materially increases the torque counteracting such change.

Over-voltages are set up rather quickly with this system on account of the fact that the voltage changes of the dynamotor are very quick-acting. The operation of the dynamotor itself is rather safe in this case, since it is of the pure series type, which makes it not very sensitive to flashing.

The system just described is, as previously mentioned, somewhat subject to instantaneous current changes, when the line voltage changes. While, as pointed out, the secondary dyna-

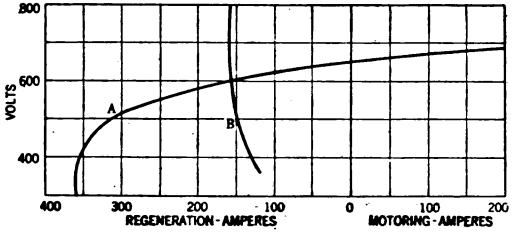


FIG. 10—SPEED CONSTANT, FIELD AMPERES VARYING WITH LINE VOLTAGE

Curve *A* = Field saturated.
" *B* = Field unsaturated.

motor voltage follows the line voltage very quickly, the self-inductive and the damping effect of the main motor fields will prevent the main motor field flux from quickly following the field voltage. To improve this condition it is desirable to change temporarily the secondary voltage of the dynamotor, and with it the field voltage, a greater amount than required for the change in flux, in order to effect the quickest change of the field of the main generator. This can be accomplished by connection as shown in Fig. 11. In this case the exciter armature *E* of a motor-generator set is excited partly, or entirely, by the motor current of the set, while the motor itself is shunt-excited. Assuming in this case a sudden voltage drop, the damping effect of the shunt field of the small motor will prevent any sudden change of the field strength, while on the other hand the mechanical inertia of the set prevents any immediate change of the speed.

Digitized by Google

Therefore, the counter e.m.f. of the small motor armature M remains unchanged and will be larger than the suddenly reduced line voltage. This will tend to diminish quickly or even reverse the current in the armature M and therefore also the current in the field H of the little generator. This in turn brings about a material reduction in the voltage of the little generator armature E, tending to reduce temporarily the main generator field appreciably. Before this current has, however, changed to the full extent and past desirable limits the voltage drop of the little generator, the speed of the little set and its field will adjust themselves to the proper condition.

This system is, therefore, very well adapted to take care of even the quickest changes in line voltage. In other respects, the system is very similar to the one previously described, except that the motor of the motor-generator set, being shunt-

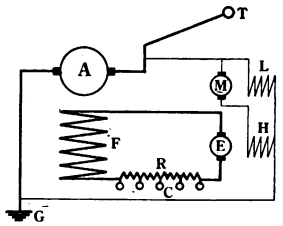


FIG. 11

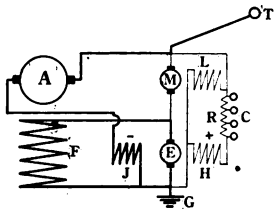


FIG. 12

excited, is subject to flash-overs, so that neutralizing windings or other special features may be required.

Since none of the previous systems is satisfactory in all respects, a system with negative compound characteristic during the regeneration period, as shown in Fig. 12, may now be considered. This system also includes a small motor-generator set, the generator E of which is, however, provided with a field winding J carrying the regenerative current and opposing the other field winding H. This general principle of providing the exciter with a field carrying the regenerative current in a demagnetizing direction is applied to the locomotives of the Chicago, Milwaukee and St. Paul Railway. If, with the system of Fig. 12, the regenerative current tends to increase, no matter whether on account of voltage drop on the line, or on account of changes in the control, the increase will cause a decrease in the voltage of the little generator, causing a consequent decrease of the main generator field which counteracts any further increase of regen-

Digitized by Google

erative current. The same feature will also be of assistance when connecting the generator to the line; even if it happens in this case that the generator voltage is quite an appreciable amount above the line voltage, excessive currents cannot exist any length of time because, as they tend to set up, they will decrease the main field excitation and reduce the regenerated voltage. The system may be provided with but few steps in the control, because it has a negative compound characteristic with curves bent up in such a way that in going from one step to the other in the control the increase of regenerated current is not very large, even though there are only a few control steps and a few curves, as demonstrated by Fig. 8. It will be seen from Fig. 12 that this system also changes the excitation with the line voltage, as was the case in Fig. 9, and this feature will of course assist in keeping overloads down in case of a change in line voltage, along lines previously discussed.

This system, while counteracting undue increases of regenerative current, is handicapped in so far as there is a certain time element between the increase of the regenerated current, the subsequent decrease of the small generator field and the decrease in field current following thereafter.

This in turn means that short-time overload surges of the armature current are possible until the main field conditions have adjusted themselves, and unless the design of the main motor is such as to be inherently very safe against flashing, flashes are likely to occur. When applied to several motors, the system is further handicapped by the fact that it is either necessary to supply a separate exciter for each motor, or, in order to distribute the load properly between the different motors with a common exciter, special load balancing devices have to be used.

It is evident that with this system any desired speed-torque curve characteristic that will best suit the particular service conditions may be obtained.

While the system is liable to give over-voltages, due to the fact that, upon interruption of power supply, the regenerated current in the field J will disappear, permitting the exciting voltage to increase, the previously mentioned time element will permit over-voltage relays to disconnect the motor circuits before the over-voltages are excessive.

The auxiliary machines of the system shown in Fig. 12, especially the motor, being of the shunt type, are not very

Digitized by Google

desirable, but could, of course be improved by substituting a highly saturated series motor or by making other suitable changes.

Some of the disadvantages of the previous system may be overcome by a system as shown in Fig. 13. In this case it is possible to use a common exciter to good advantage because each motor is self-compounding individually, and in case any of the motors should take more than its share of the load, it will automatically decrease its own field strength, which, in turn, counteracts any further increase of load. In order to obtain this effect the upper field portions which carry the regenerated armature current are arranged to counteract the lower portions of the field, which are separately excited.

The regulation of the system is accomplished by controller contacts *C*, eliminating more or less of the exciter series field turns. The operation of the auxiliary machines, which are of

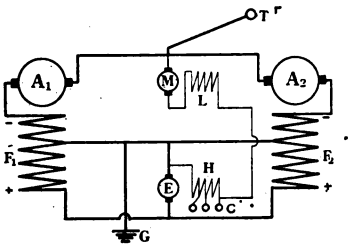


FIG. 13

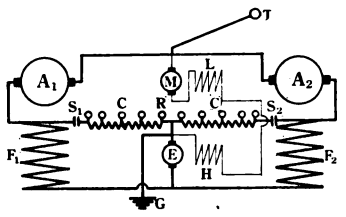


FIG. 14

the series type, should be satisfactory. On the other hand, over-voltages are liable to be established very quickly on account of the small time element previously mentioned.

One disadvantage of this system is that it requires a special motor with a two-part field winding. In some exceptional cases it might happen that a standard field control motor could be used for this system, but as a rule the ratio of turns between the two parts of a standard field control motor is not well adapted for this system. Even with a special design for the motor fields, it is somewhat difficult to obtain the proper compound characteristic for all notches, unless several main field taps and attendant undesirable complications are introduced. Furthermore, the main motor fields, if of standard size, are liable to overheat, since the resultant field is the difference of rather heavy ampere-turns in the two opposing field sections.

The system as shown in Fig. 14 fulfills practically all the re-

Digitized by Google

quirements previously enumerated. In this system, arrangements are made so that the sum of the regenerated current and the field excitation current of each main generator passes through a common resistance. The circuits are further arranged so that the voltage of this resistance subtracts from the exciter generator voltage to give the resultant voltage of the main generator fields. If we assume now that the line voltage suddenly drops, causing an increase in regenerated current, or that the latter increases for any other reason—as, for instance, changes in the control connections—it is evident that the current in the resistance also increases. This being the case, the voltage of the resistance increases also, and since the voltage of the small exciter is either constant or beginning to drop with the line voltage, it is evident that the main field voltage, being the difference between the exciter and resistance voltage, must suddenly decrease and cause the field current, as well as the field, to decrease. We have, therefore, a very quick readjustment and the desirable negative compound characteristic. It may be stated that in general a system giving each machine inherently and individually a negative compound characteristic without too much of a time element is to be preferred over any of the other possibilities mentioned, because such a machine counteracts any undue increases of current no matter whether their cause is decreased line voltage, large step in control, faulty action of control or for any other reason. The desired compound effect and speed-torque characteristic can be varied to any desirable amount in this system by merely varying the resistances to suit conditions. The loss in the resistance is in any case small, since the voltage across the resistance is hardly ever more than the field voltage, that is, only a small percentage of the total voltage.

This system is particularly advantageous with regard to connecting the generators to the line. During some experimental tests, the generators were put on the line with the no-load voltage regulated to 100 per cent larger than the line voltage and the maximum currents obtained were well within permissible limits. The adjustment of relays, therefore, does not require any great degree of refinement.

Since each motor has, as in the previous system, a separate compound effect, the system will tend to distribute the load evenly between the motors and is very satisfactory in this respect.

Digitized by Google

Over-voltages are taken care of by an over-voltage relay. In case of a loss of power supply, the regenerated voltage will, of course, rise a certain amount, because the regenerated current in the resistance becomes zero, thereby decreasing the voltage across the resistance and increasing the voltage across the main fields. A rapid cumulative voltage rise is, however, prevented because the inertia of the set prevents an instantaneous rise in speed of the motor-generator set and because a damping effect of any desirable amount may be introduced by damping windings on the field of the small generator that will prevent sudden rises of field strength, and therefore, a rise of generator voltage above the initial rise. Therefore, there is sufficient time for an over-voltage relay and the switches interrupting the exciter circuit to operate before the over-voltages have reached dangerous proportions.

The operation of the motor-generator set is safe and flashing avoided on account of the driving motor being of the pure series type. Over-speeding of the set, when running light, is avoided by driving the blower for the main motors by the shaft of the motor-generator set. The fact that the exciter set furnishes an easy means for driving a ventilating fan introduces a convenient possibility for adding forced ventilation to existing equipments now operating without forced ventilation. The addition of the motor-generator set with a fan furnishes in such a case not only the necessary excitation, but also the additional ventilation for the main motors which usually is necessary to counteract the increased losses in the motors incident to the introduction of regeneration.

Where service conditions make it desirable, the connections shown in Fig. 14 may also be used without any alteration during motoring, and give in this case a very convenient method of field control. The only difference is that in this case, the resistances carry the difference between the field exciting current and the motor load current. An increase in motor current will therefore, mean decreased current in the resistance, a decreased drop across the resistance, and increased field strength. In other words, we have a positive compound characteristic as desirable for motor operation. The system may also be arranged to use this compound characteristic up to a certain point and subsequently simply interrupt the resistance circuits by the switches S_1 and S_2, after which the motors will work as straight series motors, with the exciter armature E merely acting as a small booster adding a few volts to the line voltage.

Digitized by Google

The advantage of using one and the same connection for both motoring and regeneration is that it gives exceedingly simple control, permitting at the same time field control during motoring. On the other hand, it has the disadvantage of requiring a somewhat larger exciter, since the latter is in operation a much greater part of the time. It may also, at present, at least, be advisable to select systems which operate the motors altogether independently of the features introduced by regeneration, so that the failure of any of the regenerative parts does not in any way affect the reliability of the vehicle when motoring, and simply means that the air brakes have to be used temporarily. For this reason the system of Fig. 14 has so far

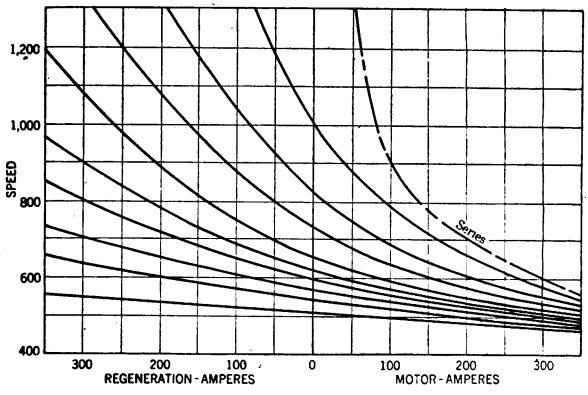


FIG. 15

been applied only in combination with the standard motor connections.

The system of Fig. 14 may, of course, be modified in a number of ways. The resistance R may, for instance, be replaced by a constant resistance, and the regulation may be accomplished by a resistance in series with the armature E (see Fig. 17). This will change the regenerative characteristic for the higher speeds as shown in Fig. 16, as compared with Fig. 15, which applies for the system of Fig. 14. Regulation may also be accomplished with a constant resistance R and means for regulating the strength of the field L (see Fig. 18).

The system of Fig. 14 could, of course, be further improved by introducing some means for temporarily forcing the change in the main generator fields in order to shorten still more the

Digitized by Google

time element introduced by the self-induction damping effect of the main generator fields; while this time element is rather small in the system shown in Fig. 14, and is of no practical importance in most cases, it may in case of very sensitive motors be desirable to reduce it further. The system of Fig. 17 shows one possible way of doing this. The resistances R fulfill the same purpose as the resistance R in Fig. 14. The two resistances are so dimensioned in Fig. 17, however, that they in themselves would give a very steep compound curve, much steeper then desirable for the operation of the vehicle. This would mean that in case of any change in line voltage or other cause for increased regenerated currents, the resistances will bring about a material decrease of the main generator voltage,

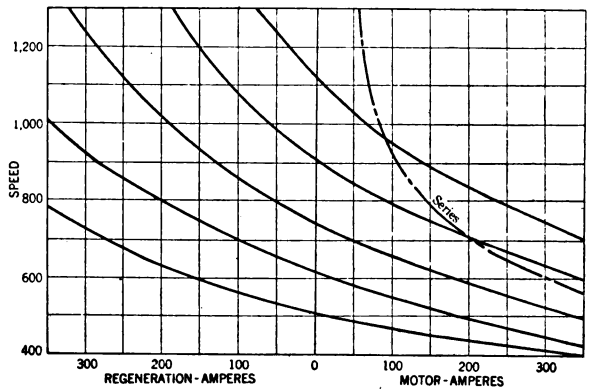


FIG. 16

and, therefore, a quick decrease of the main generator fields. The materially reduced field voltage will not, however, continue to exist because the field K on the motor of the exciter set carries the regenerated current and opposes the field L. An increase of regenerated current will, therefore, reduce the total field and cause the set to speed up, thereby increasing the voltage of the exciter armature E. This increase counteracts the decrease in field voltage brought about by the resistances R. On account of the inertia of the little set, however, it cannot speed up instantaneously, and therefore, there is a certain time element introduced in the counteracting effect. The combined effect of the resistances R and the field K may be arranged to give a fairly flat current curve and yet sudden increases of regenerative current are prevented because of the

Digitized by Google

smaller time element in the effect of the resistance R and the large time element in the effect of the field K.

A rather interesting case is shown in Fig. 18. The driving motor of the exciter set is shunt-excited and, therefore, essentially constant speed. The exciter armature is series-excited and its voltage will, therefore, increase materially with increased load, and vice versa. If we assume now, for instance, a sudden increase of regenerated current, the field voltage of the main generators will be decreased on account of the increased voltage drop across the resistances R_1 and R_2. This will mean that the current in the field H also decreases and with it the voltage of the armature E, which in turn tends further to decrease the current of the main field. It can be shown mathematically that it is possible, in this case, to obtain a characteristic with constant ratio of main field current to armature current, as shown in Fig. 3A. While, as pointed out in connection with

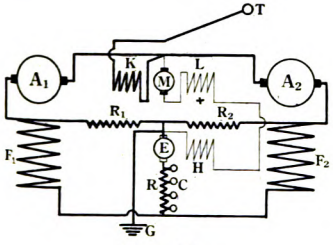


FIG. 17

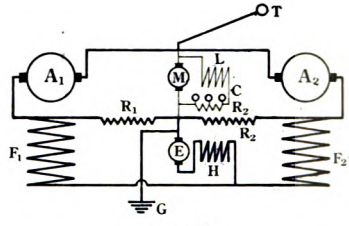


FIG. 18

Fig. 3A, such a curve is as a rule not desirable, there may be cases of motors exceptionally sensitive with regard to flashing where such a characteristic would make regeneration possible.

All systems as shown so far are, of course, limited to a certain range of speed over which regeneration can be accomplished. The maximum possible speeds are usually only limited by the maximum operating speed, of the vehicle but the minimum speeds are given by the maximum possible saturation of the motors. It is evident that regeneration cannot be effected unless the generated voltage is slightly higher than the line voltage. If, therefore, the speed is such that even with fully saturated main fields, a voltage above the line voltage cannot be induced, regeneration will be impossible. Since most standard railway motors are fairly well saturated at the hour rating, it is, therefore, usually not possible to effect regeneration for speeds much below the standard hour rating speed.

Digitized by Google

The range of regeneration below this speed can only be extended by reducing the voltage across each motor. This can be accomplished in the same manner as during acceleration, by series-parallel control, or still further, by parallel, series parallel and series control.

The fundamental principles illustrated in Fig. 14 have been very successfully applied to series-parallel control during regeneration, whereby the range for regeneration has been extended from the maximum speed down to about 35 to 40 per cent of the hour rating speed. This range is fully sufficient to cover all desirable operating speeds on down-grade in most known applications. In braking, for the purpose of reducing the vehicle speed, this range permits the regeneration of as much as 85 to 95 per cent of the stored energy which can be regained by regeneration, leaving only a very small percentage to be handled by the air brakes.

The control of the series parallel system referred to is arranged so that parallel connections are obtained automatically for all speeds for which regeneration in parallel connection is possible. For speeds below this, permitting regeneration in series connections, series connections are at once established automatically. Further arrangements are made for very low speeds which do not permit regeneration at all so that the regenerating circuits are not established. When regeneration is started in parallel connection, and the vehicle speed falls below speeds satisfactory for parallel connection, the transition to series connection is accomplished without loss of braking torque during the transition. The scope of this paper does not permit a detailed description of all the control features. It may merely be stated that the system has been developed and successfully operated with multiple-unit cars and automatic control for the regenerative braking, together with automatic control for acceleration.

The system also has been worked out for manual control with automatic maximum torque arrangements, in connection with locomotives, and one locomotive has been in successful operation on the Lake Erie and Northern Railway for the last seven months without any difficulties of main motor or auxiliary motor flashing or control failures of any kind, although the operating voltage is 1500 volts, with an occasional maximum of 2000 volts obtained during regeneration, the line being 15 miles (24 km.) long, with only one substation in the center during the first four months of operation.

Digitized by Google

The master controller handle is arranged so that acceleration is effected by moving the handle from a certain middle position in one direction, and so that braking is effected by simply moving the same handle in the opposite direction from the same middle position. The motor connections are arranged so that they are independent of the regenerative features of the control. The manipulation of the locomotive by this single master controller is, of course, exceedingly simple and naturally very much to the liking of the operator. Every regenerative braking position is a running position, so that electric braking on down-grades is possible in fine gradations over a wide range of speeds.

In order to establish the reliability of the system, tests were made in which the line voltage was suddenly changed from 900 volts to 1800 volts, and vice versa. Other tests were made by interrupting and re-establishing the power supply for various periods of interruption, and the inherent characteristic of the system, together with the control features, handles all these cases with ease.

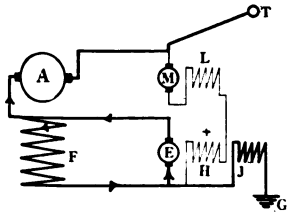


FIG. 19

Outside of the essential features and requirements to be met by an ideal system of control, a great many minor features have to be considered. Among other things, it is of course desirable to keep the exciter as small as possible in order to keep first cost and weight down to a minimum. In this connection, three different principles of excitation may be considered, namely:

1. The exciter carrying the sum of the exciting current and the regenerated current, as shown in Fig. 19. This gives, of course, a very large exciter with large commutators and numerous brushes. The principal advantage of this system, which has been applied on the locomotives of the Chicago, Milwaukee and St. Paul Railroad, seems to be that it avoids the necessity of connecting the motors to the line as generators. The arrangements in the above case are such that the motors are connected to the line in the regular way, first as motors, and the exciter is subsequently connected across the field and raises its excitation until the motor voltage overcomes the line voltage and regeneration takes place. This requires the manipulation of two separate handles and does not permit series-parallel control without interrupting the braking torque.

Digitized by Google

2. The exciter set carrying the field current only. This gives an exciter of smaller current capacity. This principle is used in the systems of Figs. 4, 9, 11, 12, 13, 14, 17 and 18.

3. The exciter set carrying the difference between the field current and the regenerative current. This gives, of course, a further opportunity for reducing the average current in the exciter and its r.m.s. capacity. It so happens, however, that with the direct-current systems previously discussed, especially for higher speeds, the maximum regenerative current is usually so large and the field current so small that the maximum currents to be carried by the exciter are about as large as in the previous case. For this reason the saving in exciter size is not very great. This system has other disadvantages—among others, the fact that the exciter works at times as a motor and at times as a generator, which in turn, makes it impossible to use a series connected machine for driving it. This, as previously pointed out, is liable to lead to flashing difficulties in the driving machine. In combination with battery excitation, as shown in Fig. 5, on the other hand, this principle is very desirable, since by proper design it is possible to charge and discharge the battery alternately and keep it charged the proper amount.

Another point of practical importance in consideration of the various systems is not only the number of steps required for control, but also the size of the current which has to be handled by the controllers. It will be seen, for instance, that in the systems shown in Figs. 4, 5, 9 and 11, the entire main field current, which is relatively large, has to be handled by the contacts. This, of course, leads to a heavier and more expensive control as well as increased maintenance cost, as compared with the systems shown in some of the other figures, for instance, Figs. 12, 13, and 18, where only the small shunt current of the exciter set is handled by the contacts.

A great many other similar systems possible for regeneration might be described and considered in detail, but it is thought that the fundamental principles have been sufficiently demonstrated by the previous examples. It may suffice to mention as further possibilities the use of exciter machines driven by one of the axles, or the main motor gears, as well as the use of one of the main motors as exciter machine for the other motors during regeneration. Numerous combinations of this sort, which are more or less promising for practical application, are possible.

While the foregoing discussions were limited to systems with

Digitized by Google

one or two voltages across the motor, that is, the line voltage and half of the line voltage obtained by series connection of the motors, it was repeatedly intimated that extended voltage variations will introduce further possibilities for regeneration. If the motor voltage could be varied at will, for instance, it would permit regenerative braking down to zero speed.

The system of Fig. 20 shows a possibility for varying the motor voltage. In this case, a booster armature B is connected in series with the armature A and arranged so that its voltage subtracts from the line voltage, thus permitting the voltage of the main motor armature A to be anything between zero and the line voltage. Since the negative booster will, in this

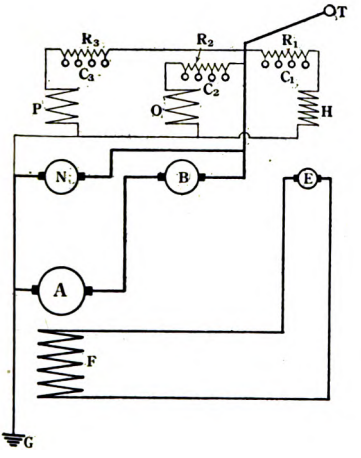


FIG. 20

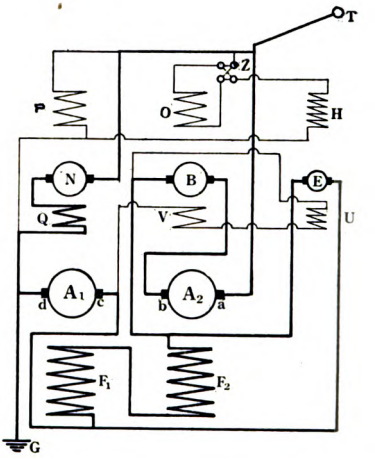


FIG. 21

case, act as a motor, the mechanical energy developed by it has to be taken up by a driven generator armature N, which returns the energy to the line. The field F is excited by a small exciter armature E coupled to the same set.

Since with the previous systems and series-parallel control it is possible to return by far the larger part of the stored energy to the line and since it is, on the other hand, not safe to dispense with the mechanical brakes altogether, the additional gain in regenerative power made possible by a system as shown in Fig. 20 would hardly warrant the addition of a booster to the equipment, espec al y since the losses of a relatively large booster set are likely to exceed the gain made by regenerating at the lower speeds.

Digitized by Google

A variable voltage system has, however, other advantages which make its consideration worth while. The existence of variable voltage permits acceleration without rheostatic losses, introducing thereby further economy in power consumption. Further, it is possible to eliminate from the vehicle a considerable number of switches now used in the main circuits for cutting out resistance and for effecting series-parallel control and to use in their stead very small switching devices in the fields of the booster set. The resistance grids proper may also be eliminated. These latter features largely compensate for the extra complication and weight of the booster set.

Instead of only reducing the line voltage by the booster, it is, of course, possible to reverse the shunt field of the booster machine and make the booster add voltage to the line voltage. It has been pointed out previously that the use of higher voltages for regeneration permits the use of stronger field currents and smaller armature currents during regeneration, which, in turn, means a smaller r.m.s. current in the motor armatures and, under otherwise equal conditions, somewhat smaller main motors. This latter advantage, however, can only be utilized if the motors are designed for higher voltages across the commutator, which, as a rule, is not very easy with some of the standard railway motor voltages. Under special conditions, however, advantage may be taken of this point.

In spite of the above advantages, the system of Fig. 20 represents hardly a practical solution, because with this system the booster set has to be quite large and heavy. It will be seen that the booster armature B carries the full motor current all the time and that its voltage varies between zero and the full motor voltage. The current capacity is, therefore, equal to that of the main motors, and while the average voltages are less than the line voltage, the maximum magnetic sections and field coils must at least be such as to carry temporarily the maximum fluxes and exciting currents. The total capacity of the booster must, therefore, be only slightly less than the total of the main motors, and somewhat similar conditions apply to the armature N.

There are, however, a number of possibilities for materially reducing the booster size. It is, for instance, quite possible to keep the booster in circuit only while the motor voltage is different from the line voltage during the first part of acceleration and the last part of retardation, and to connect the motors

Digitized by Google

directly to the line the rest of the time. This will materially reduce the r.m.s. current in the booster set.

Another possibility is to adopt series-parallel control of the motors and take full advantage of field control, which will further materially decrease the r.m.s. currents furnished by the booster set. The introduction of series-parallel control, on the other hand, eliminates one of the main advantages of booster control, namely, simplicity in the control and small number number of switches.

Another possibility for reducing the booster size is shown in Fig. 21, which reproduces a system which has been tried out in Paris (for complete description, see *Electric Railway Journal*, 1914).

With this system two motors, each of which is designed for a voltage equal to the line voltage, are connected in series with the booster B, which is again connected to another machine of equal size, N, and a small exciter armature E. The booster armature B is connected between the two motor armatures. In starting, the booster armature opposes the line voltage and the motor voltages are very low. Subsequently, the booster voltage is decreased until it is zero and the voltage of the two motors is equal to the line voltage. Then, the booster voltage is reversed and added to the line voltage until the total motor voltage equals twice the line voltage. Since the booster is, however, connected between the two armatures, the voltage to ground is in no case more than the line voltage and the voltage across any of the motor armatures is never more than the line voltage. Starting out, for instance, at the brush a with the line voltage, the armature A_2 will by its counter e.m.f. bring the voltage at the brush b down to ground voltage. The booster B will bring it up to line voltage again at brush c and the armature A_1 will by its counter e.m.f. bring it down to the ground voltage again at brush d. The armature B carries, however, in this case, for the same total motor capacity, only half as much current as in the case of Fig. 20, where if two motors were used the armature B would have to carry double motor current. The booster set of Fig. 21 is, therefore, only about half as large in capacity as in Fig. 20.

Fig. 22 shows another possibility for reducing the size of the set. In the previous figures, the booster set may be compared with a voltage transformer, with two separate circuits. With the connections in Fig. 22, the booster set may be compared

Digitized by Google

with an auto-transformer, and it has the same advantages over the other systems which an auto-transformer has over a two-coil transformer. If we assume, for instance, in Fig. 22, a starting condition with nearly zero voltage on motor armature A, we will find that nearly all the current is furnished by the armature N, while the current in the armature B is nearly zero. At half line voltage the motor current will be furnished about one-half by the armature N and one-half by the armature B. At full motor voltage, armature B will carry nearly the full current, while armature N has practically no current. While, therefore, each of the two armatures still has to be designed for a maximum voltage equal to the line voltage, it will be seen,

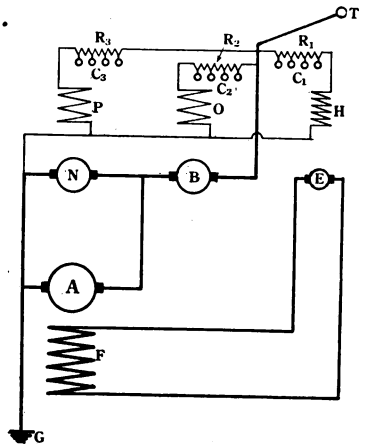


FIG. 22

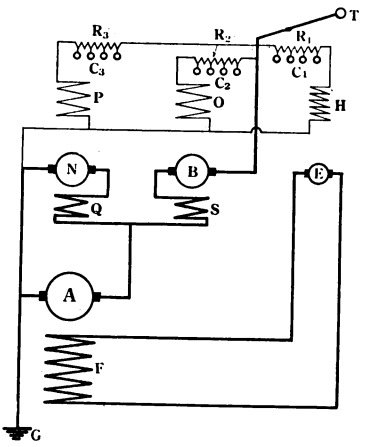


FIG. 23

for instance, that the current in the booster armature B varies between zero and the full motor current, instead of being the full motor current continuously, as in the system of Fig. 20. Consequently, the r.m.s. capacity of the booster, as well as that of the other machine N, would be very much smaller.

By properly combining two or more of the possible fundamental principles for reducing the booster size, it is quite practicable to make the set so small that the booster system may work out to be quite advantageous with regard to both weight and cost considerations.

By combining various possible methods of excitation with the various methods of booster connections, a very large number of possible combinations can be devised, a great many of which

Digitized by Google

are very promising for practical application. Further possibilities are introduced by influencing the motor characteristic by properly compounding not only the exciter but also one or both of the booster machines. Fig. 23 shows, for instance, series fields Q and S for these machines, which are so arranged that an increasing regenerative current in the armature A will decrease the voltage of B and increase the voltage of N, thereby increasing the motor voltage and counteracting a further increase of regenerative current.

The possibility of governing the main generator voltage to a large extent by the amount of the regenerative current, as shown in Fig. 23, introduces even a possibility of obtaining a fairly stable condition with a series generator, as shown in Fig. 24. We assume, for instance, that when regeneration is desired the main generator field F is reversed. The field P may now be connected to induce in the armature N a slight voltage in line with that of the line voltage, and the field O induces in the armature B a voltage slightly in excess of the line voltage. The small voltage in the armature N will now cause the main generators to pick up as series generators. As soon, however, as the regenerated current becomes an appreciable amount, the field R, being arranged to oppose the winding P, will reverse the voltage in the armature N so that it opposes the voltage of the armature A and further increases of regenerated current are prevented. The field S is arranged to decrease at the same time the voltage of the booster armature B. This same effect of the windings Q and S will prevent excessive regenerated currents in case of changes of the line voltage. A drop in the line voltage, for instance, will tend to increase the regenerated current. Such a tendency will, however, be at once counteracted by changes in the distribution of voltage between N and B, as described before. It is also a fact that slight increases in regenerated current with the connections as shown in Fig. 24 are not so very objectionable, because for a given connection of the field, the ratio of armature to field ampere-turns is always constant by necessity in a series generator.

A booster control used for both acceleration and retardation has, of course, the disadvantage that the operation of the entire vehicle is dependent upon the additional booster set, and for this reason railway men may be somewhat reluctant at the present time to introduce such a control, and will possibly prefer systems requiring an exciter set only and arranged so that the

Digitized by Google

motor operation is not dependent upon the operation of the exciter.

Another disadvantage of the booster systems is that both machines of the booster set are provided with shunt windings, making the machines rather subject to flash-overs and requiring special precautions in the design, and possibly the addition of neutralizing cross-field windings.

The systems discussed so far are all worked out with the idea of using standard or practically standard railway motors. When this condition is not imposed, further possibilities are made available. Satisfactory regenerative systems might, for instance, be devised by the use of compound-wound main motors acting as negative compound generators during regeneration, although, as previously mentioned, the introduction of any shunt winding on the main motors is undesirable, not only because it introduces complications, but also because a shunt winding with many turns is subject to high-voltage surges and consequent breakdowns, and moreover, because a shunt winding while closed increases materially the damping effect upon the fields and the flashing tendencies of the motors. Such difficulties can, however, be taken care of by the proper control and neutralizing cross-field windings on the motor.

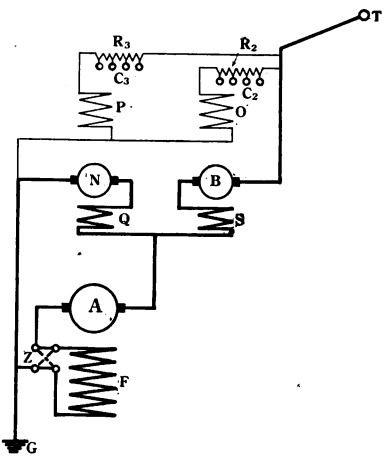


FIG. 24

Other possibilities consist in the introduction of auxiliary exciting brushes which are used during regeneration for the purpose of setting up exciting currents in the armature.

The result of regeneration upon direct-current lines may at times be rather disadvantageous with regard to voltage variations, as previously discussed. Especially with low-voltage systems with low density of traffic, voltage rises of 10 to 15 per cent above the maximum voltages otherwise obtained are not at all unlikely in a great many cases. Unless such voltage rises are premissible for all apparatus on the line, the only remedy is, in such cases, increased line and feeder copper, or some equivalent means for taking care of this condition.

Digitized by Google

With direct-current systems, regeneration may be also disadvantageous in certain cases of existing substations. While with up-to-date converting and generating machines which are all equipped with commutating poles, reverse load can, as a rule, be easily taken care of, this is at times not the case with non-commutating pole appa atus which is dependent upon a certain shifting of the brushes out of neutral to commutate successfully. With such apparatus when the current reverses the brush shift is in the wrong direction and rather bad commutating conditions will obtain, which in turn may lead to flashing.

Alternating-Current Commutator Motor System

Regeneration with alternating-current commutator motors offers in certain respects less difficulty, in other respects more difficulty, than regeneration with direct-current commutator motors.

Since alternating-current commutator motors are always provided with cross-field windings preventing armature distortion, and since they always have, moreover, relatively low commutator voltage, the flashing difficulty is largely eliminated. For the same reason the danger of over-voltages is minimized, and operation at voltages appreciably above the voltages used for motoring is usually permissible.

The alternating-current system also has the advantage that the existence of a transformer on the vehicle makes the variation of the motor voltage very easy. This, in turn, means that weakened fields at high speeds are not a necessity and that regeneration at all speeds down to standstill can be accomplished with any desired field strength, the only limitation being imposed by commutation considerations, much the same as during motoring. This permits the obtaining of any desired torque with any desired speed, with the armature and field currents adjusted to obtain minimum r.m.s. currents in either member. In general, therefore, it will be possible to effect regeneration with a lower r.m.s current in the armature than in the case of the direct-current systems with limited voltage range.

On the other hand, additional problems are introduced, due to the fact that the characteristic of the regenerating voltage must not only be right with regard to its size but it must also be correct in phase. Another difficulty is to obtain proper commutating characteristics for all speeds during regeneration, this latter problem being, in general, identical with the commutatating problem of single-phase motors during acceleration.

Digitized by Google

The proper excitation of the generators during regeneration may be obtained, in connection with alternating-current commutator motors, in three ways:

1. By the use of a separate exciter as in the case of the direct-current exciter systems.

2. By the application of exciter brushes on the main motors.

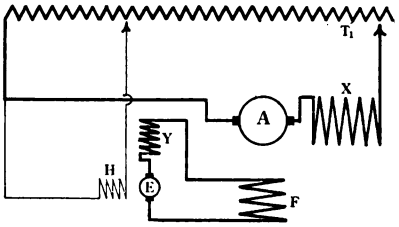


FIG. 25

3. By reversing the main fields of the motors and by operating the motors as load-excited (series) generators.

A system of the first kind is shown in Fig. 25. In order to induce a regenerated voltage of the proper phase, the main field of the generators must be about in phase with the line voltage. Since the field is purely inductive, the exciter voltage impressed upon the field must be shifted 90 deg. against the line voltage. This condition can be fulfilled by connecting the ex-

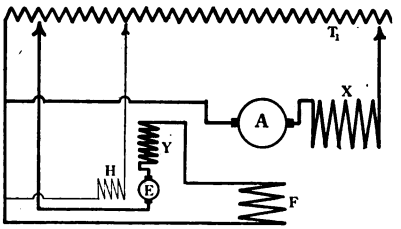


FIG. 26

citer as shown with its fields connected to the line voltage; the exciter field, being almost purely inductive, will have a phase 90 deg. shifted against the line voltage, and will also induce in the exciter armature a voltage shifted 90 deg. against the line voltage, as required.

On account of the various ohmic and inductive drops of the system, a slight phase adjustment is necessary and may be accomplished by adding a small part of the line transformer volt-

Digitized by Google

age to the excitation of the main field, as shown in Fig. 26. By properly adjusting the phase of the excitation voltage, power factor compensation can be accomplished to a certain degree.

One of the principal handicaps of the systems just described is that the exciter has to be rather large, because on account of the inductive effect of the main generator field, a large amount of kilovolt-amperes is required for its excitation.

A practical application of a system in which the exciting current was furnished by an alternating-current generator was made on a locomotive built several years ago for the Midi Railway in France. This locomotive was equipped with only two large motors, one of which was used as exciting generator for the other motor during regeneration. The system worked very satisfactorily but was later abandoned by the railway company in favor of dynamic resistance braking, because abundant water power was available and because, therefore, no advantage

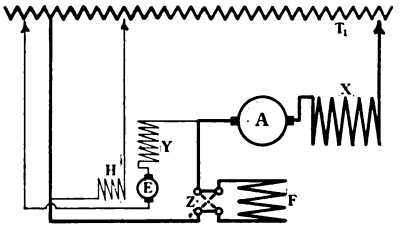


FIG. 27

could be secured by regeneration which could not be secured by a simpler arrangement for dynamic resistance braking. Another handicap in this particular case, with only two motors on the locomotive, one of which was serving as an exciter, was that only half of the total motor capacity was available for braking purposes. On locomotives with a greater number of motors this condition changes, of course, and a similar system with one motor out of a large number of motors serving as an exciter would give very satisfactory results.

Whenever all motors are to be used for regeneration, the handicap of too large a separate exciter might be eliminated to a great extent by applying a system in which the exciter furnishes only the difference between the load current and the exciter current, as shown in Fig. 27. As previously pointed out, it is possible in an alternating-current system, on account of the existing possibility of voltage regulation, to maintain any desired ratio of field to armature current. By choosing this ratio as near as

Digitized by Google

possible to 1:1, the average current furnished by the exciter can be kept very small, and although its voltage has to correspond to the necessary field voltage, the machine can be kept fairly small in size.

There is danger, however, with the system of Fig. 27, that in case of a power interruption or even during normal operation the main motor might pick up as a direct-current series generator short-circuited by the secondary transformer winding.

By separating the field conductively from the armature and connecting it in series with the stator cross field, as may be done, for instance, in the case of a repulsion connection, the possibility of direct currents may be eliminated. It is still possible, however, for low-frequency regenerated currents to be set up under certain conditions, unless special means for their elimination are devised.

A regenerative system of the second kind, with the main

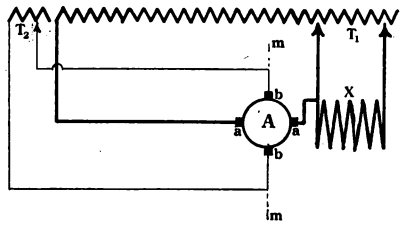


FIG. 28

motors acting as armature (self)-excited generators, is shown in Fig. 28. The operation of this system is as follows:

Assume that with the motors rotating at a certain speed the cross-field circuit X is connected to the line. It is evident that a cross field will be set up, the size of which is essentially governed by the number of cross-field turns and the voltage impressed upon the cross field X. The phase of the cross field is shifted 90 deg. against the line voltage. This cross field will naturally induce by rotation a voltage between the exciter brushes $b\ b$, which is proportional to and in phase with the cross field. If we now close the exciter circuit, this voltage will set up a magnetizing current which, in turn, excites the field along the axis $m\ m$. Since the circuit is practically purely inductive, the magnetizing current as well as the field will be shifted 90 deg. against the voltage induced between the brushes $b\ b$ and, therefore, shifted 180 deg. against the line voltage. This field will, therefore, induce a voltage in the armature between the working brushes $a\ a$ which is opposite to the transformer volt-

Digitized by Google

age. The value of the generated e.m.f. can easily be adjusted by adjusting the voltage impressed upon the cross-field circuit and making it sufficiently in excess of the impressed effective armature voltage so that regenerated currents are furnished to the transformer. The small transformer winding T_2 in the armature exciting circuit is provided for the purpose of correctly adjusting the phase of the exciting field, which is somewhat influenced by the ohmic drops, etc., in the exciting circuits.

Such a system is advantageous insofar as it eliminates the necessity of auxiliary rotating apparatus for regeneration. It also permits of power factor compensation during regeneration, and possibly during motoring, within certain limits.

The system is, however, handicapped due to the fact that the armatures and also the commutators for the main motors have to be increased in capacity because they carry the exciting currents in addition to the load currents. This, in view of the space limitations existing for the main motors in connection with railway work, is quite a serious handicap. Another disadvantage of the system is the necessity of additional brushes around the commutator. With the large number of brushes inherent with single-phase motors, even of the stator-excited type, the addition of extra sets of exciter brushes becomes in many practical applications a rather serious problem.

Both of the previous systems have essentially a shunt characteristic but the current curves are not as flat as they would be with a direct-current shunt machine, on account of the reactive drops present in alternating-current machines and in the rest of the system in addition to the ohmic drops. Since, moreover, the low voltage of alternating-current motors, and the absence of armature distortion, make flashing unlikely, the curves obtained with these systems are satisfactory in many cases. The excitation is in both cases proportional to the line voltage, so that variations in the latter are always compensated by proportional variation in the field strength.

When desirable, steeper curves can be obtained for the separate exciter system as shown in Fig. 29, and for the self-exciting system as shown in Fig. 30.

The small transformer T_2, as shown in Fig. 29, being connected in series with the load current, is arranged so that its secondary voltage subtracts from the exciter voltage. An increase in load, therefore, means decreased exciter voltage and decreased generator voltage. In other words, we obtain a negative compound characteristic which in its purpose and effect is similar to such

Digitized by Google

a characteristic when obtained in connection with direct-current motors.

The working principle of Fig. 30 is as follows:

The stator field connected in series with the load current is arranged to oppose the magnetizing effect of the armature magnetizing circuit. If, therefore, the load increases, the negative magnetizing effect of the stator field increases. On the other

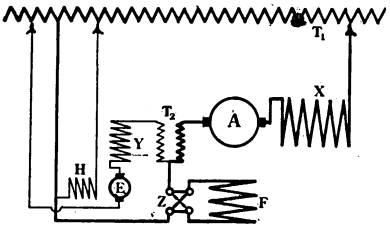


FIG. 29

hand, it must be considered that the voltage induced by rotation between the exciter brushes has remained unchanged. The demagnetizing effect of the stator ampere-turns will, therefore, tend to set up increased magnetizing turns in the armature exciting circuit. This in turn, will increase the part of the exciting voltage taken up by the inductance *I*, leaving only a smaller part of the total voltage generated by rotation to be consumed by the self-induction of the main field in the armature.

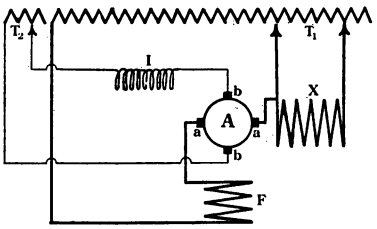


FIG. 30

This, in turn, means that the main field must be smaller than before and that, therefore, lower working voltage is induced.

In this manner it is possible to obtain any desired amount of compound characteristic.

The third possibility for obtaining regeneration by reversing the main field of an alternating-current series motor, for instance, is rather interesting insofar as such an alternating-current series generator acts in a way entirely different from a series direct-

Digitized by Google

current generator. A suddenly decreased line voltage will not increase the regenerated current of the line frequency as in the case of direct current, but will tend to decrease it. Similarly, an increased speed will decrease this regenerated current. These changed conditions are brought about by the inductive drops of the machine and their phase relations to the load current, especially the large inductive drop of the main field. While this characteristic of the alternating-current series generator would make its use for regeneration possible, other difficulties have to be overcome for a practical solution along these lines. The system is handicapped by the strong tendency of the generators to pick up as direct-current generators with the secondary transformer winding serving practically as a short circuit. Even if direct currents are made impossible as in the case of a repulsion motor, there is a strong tendency for low-frequency currents to be set up, causing trouble. In view of these and other difficulties, this method of regeneration has so far not been seriously considered for railway application in this country, and a detailed discussion of its theory is, therefore, hardly within the scope of this paper. Undoubtedly, it has, however, certain possibilities for the future.

The difficulty of connecting alternating-current generators to the line is materially reduced as compared to direct-current motors because the inductive effects of an alternating-current system materially reduce the tendency towards current peaks. The introduction of a certain amount of compound characteristic by the means previously described will, of course, further assist in keeping current peaks down.

The various considerations and methods possible to take care of proper commutation during regeneration are very numerous, so that a complete analysis of them would easily take as much space as the present paper. It is, therefore, considered advisable to dispose of this subject by merely stating that satisfactory commutation can be obtained during regeneration, although certain complications in the control may have to be introduced for this purpose, under certain conditions.

The considerations in connection with regenerative control referring to the transmission, transforming and generating systems are with single-phase commutator motors no different from these previously discussed in connection with the three-phase and the phase converter system; in other words, there is usually no particular difficulty and the changed conditions can be taken care of by very few and simple safety devices.

Digitized by Google

Vapor Converter System

The use of vapor converters in connection with electric railways, while not of present commercial importance, may be so in the future, and, therefore, may be mentioned briefly in this connection.

When a vapor converter is used in a substation, conditions are much the same as in ordinary direct-current systems. One difference is, however, that the regenerated power coming back at times to the substation in the case of rotating converting apparatus can readily be returned to the alternating-current generating system and used up by other loads of this system, while with the present practical forms of vapor converters this is not possible. It is, therefore, necessary to dissipate a larger percentage of regenerated power in the substations by resistances. On the other hand, the vapor converter substation is free from certain dangers caused by voltage rises in substations with rotary apparatus as previously discussed.

When the vapor converter is used on the vehicle, the problem of regeneration seems, at least at the present time, rather difficult. While certain suggestions have been made for rectifying devices, transforming direct-current power into alternating-current power, their commercial development seems to be far off. The only possible way for returning regenerated direct-current power to an alternating-current line seems to be, therefore, the addition of a small synchronous converter or motor-generator set to be installed on the vehicle and used during regeneration. Such a solution of the problem appears, of course, to be cumbersome, heavy and complicated.

Conclusions

In view of the numerous possibilities for successful regeneration, only a few of which have been considered in this paper, it is to be expected that regenerative braking will soon assume great commercial importance. It should, therefore, be exhaustively considered in any new electrification, and the time is approaching when its possible application should be investigated for the larger existing non-regenerative installations. In view of the practical advantages of regeneration for heavy railroad work, it is even quite likely that regeneration will in time become one of the factors which will win some railroads, now operated by steam, over to the electric cause.

Digitized by Google

Presented at a section meeting of the American Institute of Electrical Engineers, San Francisco, Cal., November 24, 1916.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

INVESTIGATION OF SUSPENSION INSULATOR DETERIORATION

BY J. E. WOODBRIDGE

ABSTRACT OF PAPER

This paper gives an outline of the investigation of suspension insulator deterioration undertaken by Professor H. J. Ryan and Assistant Professor J. C. Clark, and explained farther in their papers. It cites the origin of the investigation, the limiting factors encountered and methods employed to overcome such handicaps.

The results of this investigation are admitted as disappointing and inconclusive on the causes of deterioration, although several causes previously considered probable have been eliminated.

THE TROUBLES experienced by operators of high-voltage transmission lines, due to deterioration with age of the dielectric strength of cemented porcelain suspension insulators, combined with the inability of ceramists and engineers to agree upon a satisfactory explanation of such deterioration, have induced the power companies of California to join forces in a scientific investigation of this deterioration. The results of this study, in so far as results have been obtained to date, are presented in full in the accompanying papers by Professor Harris J. Ryan and Assistant Professor J. C. Clark. The companies interested in this investigation to the extent of contributing to the expense of same are; the Pacific Gas and Electric Company, Pacific Light and Power Corporation, Sierra and San Francisco Power Company, San Joaquin Light and Power Corporation, and the Southern California Edison Company.

The investigation began as the outcome of discussions on the subject between Mr. J. P. Jollyman, of the Pacific Gas and Electric Company, Mr. H. A. Barre, of the Pacific Light and Power Corporation, and the writer, representing the Sierra & San Francisco Power Company. These discussions resulted in a conviction that megohm values of infinity determined by the commercial megger, that is, anything above 2000 or 5000 megohms, covered a wide range of porcelain values, an investigation of which might develop insulation resistances characteristic

Manuscript of this paper was received November 23, 1916.

Digitized by Google

of durable versus non-durable porcelain. It was even thought that if deterioration is due to porosity, and if suitable apparatus could be developed for measuring much higher insulation resistances, a characteristic resistance might be found for porous porcelain, even when dry. It is obvious that if these hypotheses had proved correct, it would be possible for insulator makers to measure such porosity by electrical means in new porcelain, and determine in advance what insulators would deteriorate, which would in turn allow them to determine what method of manufacture would produce the most durable product in this respect.

It was also the idea of these engineers that insulation resistance measurements made under dielectric stresses more nearly approximating those of commercial service than the 1000 volts of the commercial megger might be of correspondingly greater value. The inherent difficulties of such measurements with alternating voltages, due to the extremely low power factor of insulator leakage, at once suggested the use of the kenotron for the supply of continuous current at the voltages desired.

A paper presented by Professor Ryan before the San Francisco Section of the Institute on March 31, 1916, described such measurements made at Stanford University under a pressure of 4000 volts d-c. derived from a kenotron with a sensitive galvanometer, the combination giving a range up to 800,000 megohms distinguishable from infinity. This equipment as then developed by Professor Ryan obviously extended the range of meggering to values 160 times greater than those of the commercial megger. A further extension of this line of investigation was then proposed to Professor Ryan with the request that he obtain the consent of the University authorities for the use of the high-tension laboratory and its equipment for this study during the 1916 summer vacation. Professor Ryan obtained this privilege and agreed to serve as a member of the committee having charge of the work, to which service he devoted the greater portion of his time during the vacation period. The necessary funds were contributed by the above mentioned companies and the work was started under the direction of Professor Ryan, the above mentioned engineers, and Assistant Professor J. C. Clark, who was employed actively on the work with assistants throughout the summer. Insulators were contributed by the various power companies above mentioned and by the Great Western Power Company, also by several manufacturers, usually in lots of 100, these insulators being of all the

Digitized by Google

well known makes, and, in so far as possible, of various ages, colors and previous conditions of servitude.

The results of this investigation to date may at the outset be admitted to be disappointing, as the ambitions of the promoting engineers have not been realized. Water logged elements have been dried out and restored to insulation resistances equal to those of the least porous. By the use of continuous current at 25,000 volts and of galvanometers of great sensitiveness, infinity has been thrown above the resistance of any single piece of porcelain procurable, measurements being possible up to ten million megohms. As might be expected, this has been accomplished only by the exercise of great care and ingenuity in the matter of guarding against leakage. The characteristic resistance of porcelain suspension insulators of common shapes and sizes has been found to run between one-quarter and one and three-quarters million megohms.

Conclusive positive information on the causes of deterioration has not been obtained, but considerable negative information has practically eliminated several causes previously considered probable. Mechanical loads have been proved to have little or nothing to do with the case. Stresses set up by expansion and contraction with temperature changes appear to have little or nothing to do with deterioration in properly designed and annealed elements. There are indications that these stresses are as great in insulators without attached hardware as in those complete with cemented metallic attachments; also, that such stresses are as great in porous insulators as in those more thoroughly vitrified.

A study of porosity has shown that much, if not all wet process electrical porcelain is slightly porous, some of this porcelain being more suitable for filtration use than for the exclusion of moisture. Aside from this exception, the term "slightly porous" here means porous to such an extent that moisture may in the course of years creep into minute crevices, forming conducting paths which eventually reduce the distance between terminals of the insulator, (Considering such paths as conducting extensions of terminals into the mass of the porcelain) until the dielectric stresses between terminals will rupture the intervening material. Local heating in the non-porous barriers separating such conducting paths probably assists the final failure of the remaining dielectric strength. This investigation has shown that porcelain has an extremely high negative rate of change of resistance with tem-

Digitized by Google

perature. Of the specimens tested, the rate of change may be stated as a loss of 99 per cent of the resistance with a rise of 45 deg. cent. from ordinary temperatures.

This partial porosity has so far been found extremely difficult of detection. We have found it impossible to devise any means of materially hastening the absorption of moisture above the rate inherent in ordinary line use, which often requires several years before the deterioration is apparent.

The difficulty in making porcelain bodies absolutely impervious to moisture is obviously due to the fact that porcelain by the very nature of its formation cannot be completely liquified in the process of vitrification as can other materials, such as glass. This leads to the consideration of materials having the desired mechanical and electrical qualities, which can be liquified and cast in a mold. Of these the most promising in both electrical and mechanical characteristics that has been brought to the attention of the committee is fused silica. This material has a high dielectric strength, and an extremely low coefficient of expansion with temperature. Its behavior when subjected to high dielectric stresses of sustained high frequency gives promise of very desirable characteristics in the qualities of dielectric strength, local heating under high potentials, and change of resistance with temperature.

It is the wish of the committee that others investigating this subject, or in a position to do so, may benefit by the ideas developed by this committee's work to date, and may carry on the work along the various lines indicated, which this committee has not been in a position to carry to completion.

Digitized by Google

Presented at a section meeting of the American Institute of Electrical Engineers, San Francisco, Cal., November 24, 1916.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

CERAMICS IN RELATION TO THE DURABILITY OF PORCELAIN SUSPENSION INSULATORS

BY HARRIS J. RYAN

ABSTRACT OF PAPER

The fundamental requirements in satisfactory high-voltage line insulators are summarized and particular emphasis is placed upon the need for coordinated study of service durability. The effect of porosity upon durability is explained in detail and an appeal made for the establishment of a practical porosity elimination test.

The manufacture and structure of electrical porcelain is studied from the viewpoint of the ceramist, with many quotations and illustrations taken from the Transactions of the American Ceramic Society.

The author briefly states the conclusions at which he has arrived and gives a very complete list of references and notes.

DURABILITY is one of several fundamental requirements in a satisfactory high-voltage line insulator. These requirements are:

1. Electrical Requirements.
   a. Electrical strength of dielectric.
   b. Refractoriness of dielectric.
   c. Design of electrical features.
2. Mechanical Requirements.
   a. Mechanical strength and toughness of dielectric.
   b. Design of mechanical and thermal features and their coordination with requisite electrical features.
3. Durability Requirement.
   Minimum attainable deterioration.
4. Cost Requirement.
   Best insulators that the art can produce at a minimum cost which the practise can afford.

The modern porcelain suspension insulator is generally accepted in the present state of the art as meeting the above requirements to the greatest extent. In respect to these requirements the service it renders is reasonably satisfactory except as to durability. Effort is now being made by manufacturers and engineers to produce and to accept only such high-voltage porcelain insulators as will not fail under ordinary conditions of use

Manuscript of this paper was received November 22, 1916

Digitized by Google

or non-use in ten years or more. As yet there is no assurance that this result has been accomplished. If the causes of the failure of insulators with time were fully understood, more effective work could be done to eliminate them. At present, after much effort in many quarters, these causes are known and understood only to a limited extent.

Hardly any of the requirements of an insulator stand alone and unrelated to the rest. Particularly is this true of durability. Most of the features and of the properties of the materials that constitute an insulator are related to its durability. It is not reasonable to expect, therefore, that decided improvement in the durability of the insulator can be made without a thorough going study by which full knowledge will be developed of all the facts for the materials and their forms that enter into the make-up of the insulator.

There are two distinct phases of durability:

1. Ability to endure sufficiently an adopted set of *acceptance tests*.

2. Ability to endure operating service conditions and the action of the elements during a reasonably long period of time, *i.e.*, ten years and upwards.

We may for the present call the former *acceptance durability* and the latter *service durability*.

Insulators must be bought and paid for largely through the results of acceptance tests. On account of the great length of time involved, few if any can be bought on the basis of an ultimate durability in service which years alone can determine. The present day suspension insulator was introduced nearly ten years ago and service durability results are now accumulating rapidly. It is generally conceded that the difference between acceptance and service durabilities is too great and must be reduced. The remedy is being sought for and applied through causes of failures in and out of service as related to the past and present states of the art. A large amount of coordinated effort of all concerned and able to take part is required to discover these causes. The study of the service durability of high-voltage insulators must have a number of well defined and not-to-be-forgotten *points of application* in order that the greatest advance in this durability may ultimately be attained; they are:

1. Insulators that have and have not failed in service.
2. Insulators that have deteriorated when not in service.
3. Laboratory treatments that will cause insulators to fail.

Digitized by Google

4. Factory materials, design and technique in relation to subsequent failure of insulators.

5. Laboratory science studies of everything that can be perceived about the materials, their form and assembly for insulators.

6. Coordination of all known knowledge that can have any possible bearing upon insulator durability.

Studies have to be made by factory and transmission engineers and by ceramists, geologists, chemists and physicists at all of these specified points of application. Everywhere the work amounts to little more than a beginning and much more remains to be done if the porcelain insulator is to be made thoroughly reliable in practise.

In a conference with Dr. J. C. Branner, a geologist with a wide knowledge of rock, clay and earth products, it was learned that high durability must not be expected of *porous* bodies even when they are constituted of porcelain. To retain the original integrity of clay products generally their vitrification must be carried far enough to make them virtually proof against the absorption of moisture. In witness thereof, he exhibited a porous clay product dish covered with an imperfect glaze. A student in biology for a comtemplated experiment had dissolved a salt in some water placed in this dish. Interest in the undertaking was then lost and the dish containing the solution was allowed to stand in the laboratory untouched for a number of weeks. In the meantime the solution entered quite generally into the pores of the porous dish body. Later as the water evaporated from the dish and from its porous body salt was deposited throughout the pores. The salt formed crystalline structures that developed excessive internal mechanical stresses throughout the dish. Complete ruin of the dish resulted, chiefly through the production of large and small spalls and cracks. As a structure, however, the dish had remained whole. In respect hereof materials in solution are divided into two classes:

1. Materials that expand when passing from the liquid to the solid state by freezing or by crystallizing from a saturated solution

2. Materials that do not expand in the same circumstances.[14]

The former materials only produce the mechanical injury in porous structures though injury by electric conduction that each class of materials may cause, so long as any moisture remains in them, must ever be kept in mind.

Regarding the claim that ample vitrification of porcelain will

14. For references see notes at end of paper.

Digitized by Google

make it brittle and mechanically unreliable, it was learned from the same authority that the way out of the difficulty should be to select materials that would have to be vitrified at higher temperatures resulting in a greater toughness of product. As evidence thereof the production of satisfactory paving brick in our country was referred to. This is accomplished by ample vitrification of materials so chosen and proportioned that high temperatures must be applied for the result. The enhanced durability of the brick is worth more than the increased cost of vitrifying at the higher temperatures.

It has long been known that porcelain for high-voltage line insulators affords no dependable service durability when made by the dry process and that a fair service durability for a large portion of the product is rendered when made by the wet process. In dry process porcelain the porosity can be reduced to one per cent only with difficulty,[1] whereas in a major portion of the high grade wet process porcelain the porosity is, by comparison, very low *i.e. one tenth* per cent or less.[2] This practical experience establishes the fact that the lowest degree of porosity that the art can be made to produce is a service durability requirement of the highest importance. Porous porcelain when waterlogged becomes virtually an electrolytic conductor and a failure as an insulator. Its failure to insulate would be less decisive if under the circumstances its temperature-resistivity coefficient were not negative in sign and so high in value. As soon as local heat is generated the whole current flowing through the porcelain body must inevitably be concentrated upon a route so narrow that intense heating occurs resulting in fusion or burning and the production of a conducting core.

Portland cement is generally used to attach the metal pins and caps to the porcelain insulator bodies. The details of cement curing are well known. First a saturated solution is formed of the new cement in the excess of water present. When the insulator body is porous such saturated solution is absorbed. Later all free water evaporates and the material in solution in the pores of the porcelain remains as crystals producing great mechanical stresses as already shown.

Insulators are carefully designed to minimize cracking of the porcelain body by thermal expansion stresses. With porcelain sufficiently porous to permit cement crystals to form within the body it would seem to be too much to expect of any design that no cracks would occur. The combination of mechanical stresses

Digitized by Google

produced by the crystals and by differential thermal expansions must inevitably produce more cracks in the porcelain body than from these causes acting alone.

Porous porcelain in an insulator captures moisture in damd weather and liberates it in dry weather. Each weather cycle will deposit, however minute, a certain quota of soluble salts. Thus eventually salt will have accumulated in the porcelain body to such an extent that it must fail as a dielectric due to cracks in dry weather increased by sudden temperature changes or by electrolytic conduction in wet weather or all together in a manner difficult to recognize. Old cement is a decidedly porous body that must also tend to swell and produce large mechanical stresses when foreign crystals have been deposited in its pores. It is thus seen that porous porcelain must eventually fail as an insulator. Likewise the porosity of the cement used in attaching the caps and pins must, for much the same reason, be a cause that aids in bringing about the failure of an insulator with time. It is said that the high grade electrical porcelain is fired to cone twelve temperature, 1355 deg. cent.[4] The maker claims that an underfired body will be tough and mechanically reliable and an overfired body will be brittle and mechanically unreliable. It is a well established fact that high-grade porcelain underfired is decidedly porous and unfit,[1] that from an electrical viewpoint only, fully fired porcelain has its pore systems amply closed (rendered vesicular) and overfired porcelain bodies are apt to have a "bleb" structure due to the concentration of gases sealed up in the pore system or to the evolution of gases in reactions that may occur.[1]

In view of these things it should not be permitted to meet mechanical loading requirements by the expedient of underfiring which is bound to reduce service durability. The assumption that the cracking of insulator porcelain bodies may be avoided by annealing[7] and by form design must in time be a disappointment if porosity of porcelain and of cement are permitted.[8]

The foregoing considerations indicate that acceptance tests must include a practical porosity elimination test as soon as it can be devised. Professor Creighton has indicated[9] and the work reported in the present papers show that slightly porous porcelain does not by all ordinary means admit moisture quickly to any considerable portion of the body. It is true that ceramists take the amount of water absorbed by a porcelain as a measure of its porosity. However, unless the test specimen is thin it is

Digitized by Google

broken into small fragments before being immersed in water. Even so it is quite likely that the best porosity measuring technique of the ceramist will have to be improved upon in order to measure with fair exactness the low values of porosity that occur in high-voltage porcelains offered for acceptance. The above remark, that it is ordinarily difficult to cause water to penetrate slightly porous unglazed porcelain, applies only to porcelain in bulk of insulator size.

The hunt is being continued for methods by which slightly porous porcelain can be made to take up water quickly to a considerable depth thereby correspondingly decreasing the insulation resistance and thus to determine electrically the existence of the porosity without injuring the insulator. The following tests were applied to unmounted insulators having caps unglazed inside and out and which were known to be porous because their resistance rose through oven treatment. The last method tried and here listed for detecting porosity did not involve water absorption:

1. Two insulators were immersed in live steam for four hours without result as to moisture absorption.

2. They were immersed in live steam for four hours during which cold tap water was circulated through the interior of the caps without moisture absorption result.

3. Using tap water electrodes, 25,000 continuous volts were steadily applied through the cap of one of these units for a period of two hours during which the current flowing was observed in the high-duty megger outfit. No change in the resistance of the insulator occurred, showing that moisture could not have been driven to considerable depths by the electrical and capillary forces during the time of the test.

4. A trial suggested by Mr. J. P. Jollyman: Dried porcelain known to be porous and non-porous insulators were megged, using 10,000 continuous volts applied through the outer layer of the cap and megged again after soaking in tap water over night. The overnight soaking caused the resistance of the porous insulators, only, to be lowered decidedly.

5. The caps of dry unmounted porous and non-porous insulators were subjected to ten kilovolts, sustained uniformly at 325,000 cycles per second for five minutes. Temperatures of the outer crowns of the caps were taken immediately before and after the test. After immersion over night in tap water the tests were again repeated. The heating of the dry porous insulators

Digitized by Google

was slightly more than of the dry non-porous while for those soaked in water over night the heating was decidedly greater for the porous than for the non-porous insulators.

6. Trial by gaseous conduction in lieu of electrolytic conduction: Dry porous and non-porous insulators were megged again with all conditions the same except that the electrode facing the outer surface of the caps was constituted of ionized gas liberated from an adjacent needle point connected to the galvanometer and properly guarded. The results showed that slight porosity can not be located by this method.

A look into the Transactions of the American Ceramic Society reveals the fact that ceramists have, in recent years, conducted

By permission of the American Ceramic Society

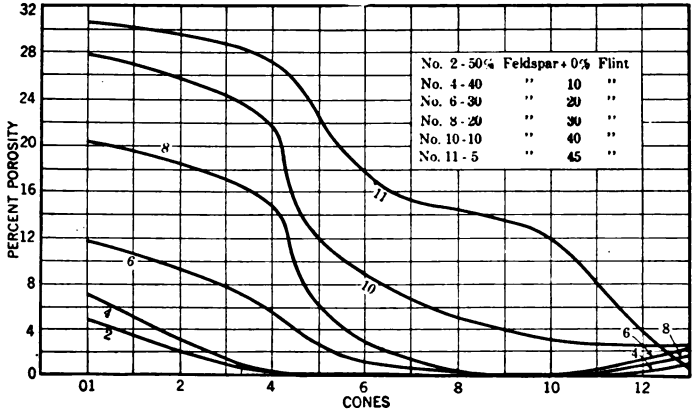


FIG. 13

several investigations of electrical porcelains that are of interest to transmission engineers. As the contents of these transactions do not appear to be generally known the author ventures to present certain diagrams and abstracts taken from these papers.

In a study of explorations to find porcelains that should be suitable for high-voltage insulators at the University of Illinois, Bleininger and Stull[10] made up about 450 separate and distinct specimens of clays, spars and flints varying in kind and proportions. By permission of the American Ceramic Society Figs. 13, 14, 15, 29, 30 and 31 of the original paper are reproduced herewith. The first three are *porosity-temperature-composition* diagrams and the last *three* are corresponding triaxial diagrams in

Digitized by Google

By permission of the American Ceramic Society

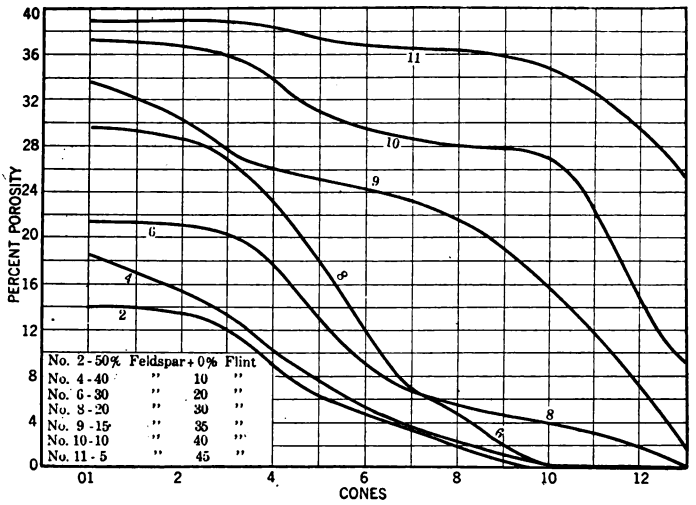


FIG. 14

By permission of the American Ceramic Society

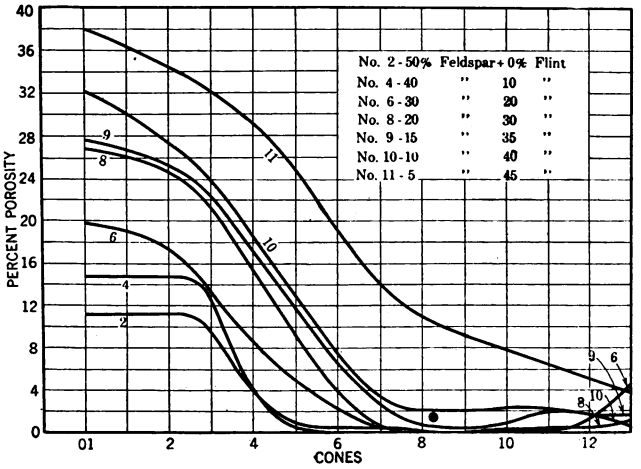


FIG. 15

Digitized by Google

which the *dielectric strength* (by slowly applied voltage required to puncture under oil) and *composition* are coordinated topographically. These diagrams are self-explanatory though a few corresponding quotations from the paper are helpful.

"All porcelain bodies absorbing not more than 0.1 per cent of water, by weight, upon boiling in vacuo are considered vitrified."

"*Tennessee Ball Clay.*" "The less refractory character of this clay is indicated by the large range covered by the temperature area below cone 10, (1305 deg. cent.)". Figs. 13 and 29.

"*The North Carolina Kaolin* offers quite a contrast to the last material, in as much as its vitrification area is quite small at

By permission of the American Ceramic Society

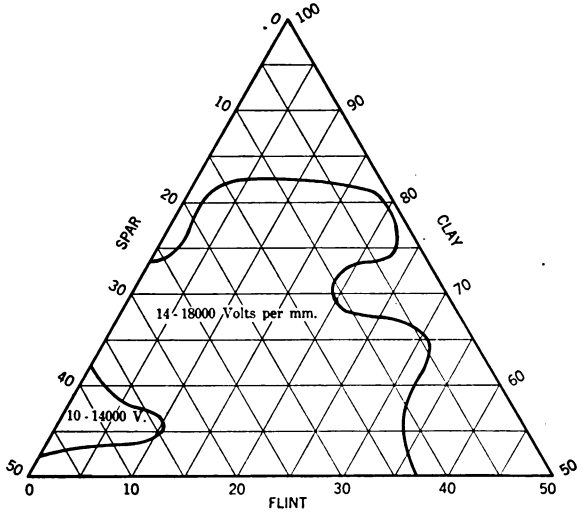


FIG. 29—TENNESSEE BALL CLAY

temperatures up to cone 10. The range is decidedly increased at the higher temperatures." Figs. 14 and 30.

"*The English China Clay* differs from preceding clays in that its vitrification boundaries slope far more gradually in spite of the fact that its alkali content is not greater than that of the North Carolina kaolin." . . . "It is evident that this material differs considerably from similar American clays in this respect due to its structure or fineness of grain. Its vitrification area is quite large." Figs. 15 and 31.

"*Dielectric Behavior.*" The voltages have been arranged in *three* groups which are: less than 10,000 volts per mm. from 10,000 to 14,000 volts per mm. and from 14,000 to 18,000 volts per mm."

Digitized by Google

By permission of the American Ceramic Society

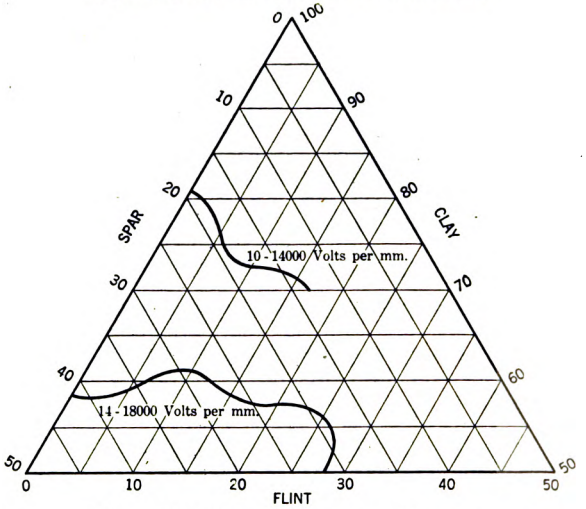


FIG. 30—NORTH CAROLINA KAOLIN

By permission of the American Ceramic Society

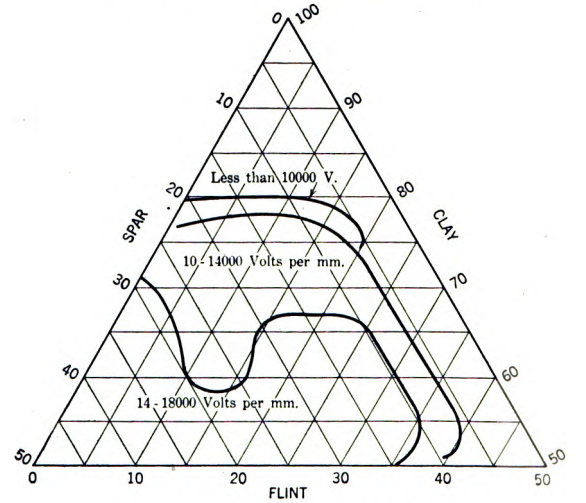


FIG. 31—ENGLISH CHINA CLAY

Digitized by Google

. . . 'The electrical resistance (strength against puncture under oil) seems to depend more upon sound vitrification and good mechanical strength than chemical composition, excepting, of course, in so far as the latter governs the vitrifying behavior." Figs. 29, 30 and 31.

Later these studies were continued at the University of Illinois by B. S. Radcliffe under the supervision of Professor Stull.[11] A number of decidedly porous porcelains were found having (when dry) high dielectric strength. The results obtained are given in the triaxial diagram Fig. 5 of this paper, reproduced herein by permission of the American Ceramic Society. Used for high

By permission of the American Ceramic Society

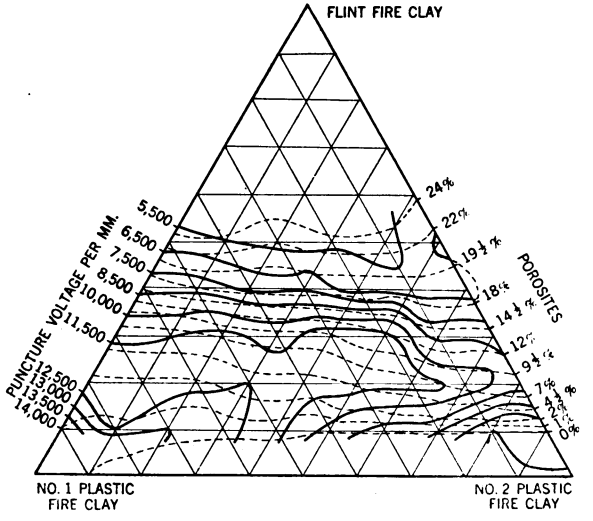


FIG. 5—RELATIVE POROSITIES AND DIELECTRIC STRENGTH OF FIRECLAY MIXTURES BURNED TO CONE 12½

voltage line insulators, however, these porcelains would in time become water-logged and salt laden and would eventually fail. Nevertheless the results are deemed of real importance to the transmission engineer for they corroborate the corresponding fact reported in the present set of papers and earlier by Bang,[12] viz. that dry porcelain when decidedly porous may possess a fairly high dielectric strength. Initial dielectric strength can, therefore, be no complete measure of the electrical service durability of a high-voltage line insulator.

In a critical study of the foregoing results in ceramics one is brought to the conclusion that the desirable qualities in electrical

Digitized by Google

porcelain refractoriness and, therefore, toughness and vitriousness or imperviousness, are to be gained only through a high content of flint fired at an amply high temperature.[15] Fused flint, quartz or silica as it is variously called is thus indicated as the limiting outcome of the use of more flint and less spar and clay. Quartz goes gradually into fluidity only at a higher temperature than platinum. In giving up its crystalline structure through heat it is subject to an extraordinary degree of cracking, whereby it captures large quantities of air or other gases in the furnace.[16] It is difficult to fluidify the quartz without evaporation sufficiently to liberate such entrained gases. These difficulties have been overcome in recent years sufficiently so that chemical ware of fused quartz can now be afforded to a limited extent. Once fused and freed of gas "blebs", quartz has incomparable electrical, refractory and thermal-mechanical properties. It is not injured if when red hot, it is plunged into cold water. When it can be fluidified by special treatment in an electric furnace sufficiently to be cleared of all entrained gas it may then be cast in cold metal moulds to form high voltage insulators. Until this can be done with quartz or some materials having much the same properties, porcelain will doubtless remain in use for such purpose.

Wet process porcelain is roughly moulded to form in the plastic state, then dried to the "leatherhead" state, removed from the moulds, tooled to exact form, slowly fired and slowly cooled without further resort to moulds. This solid vitrification without the use of moulds and without deformation is at once its greatest advantage and disadvantage. The initial stages of the process develop a pore system in the green porcelain body that can be eliminated or rendered vesicular only by the best possible technique applied to each and every piece in all stages of the process. Since this is not practicable on a large scale it is inevitable that, in the factory production of high grade electrical porcelain some of the low grade must be produced along with it. The importance of all improvements and of tests for the elimination of structurally imperfect and appreciably porous porcelains and of the operating strategy of thoroughly shuffling the finished insulators so as to minimize the likelihood of more than one unrecognized defective insulator being mounted in the same string is made manifest by a study of these results obtained by the ceramists.

An investigation by Weimar and Dunn[13] undertaken in the department of ceramics of the University of Ohio yielded valuable knowledge as to the manner in which insulating qualities of porcelains vary with temperature. They give a table found in

Digitized by Google

the Transactions of the Royal Society of London. It includes temperatures and corresponding specific resistances of a "porcelain" ranging from 1.63 deg. cent. to 81.93 deg. cent. Inspection of the contents of the paper reveals the fact that porcelain as here reported lost resistivity within the stated temperature range at the uniform logarithmic rate of 100 to 1 for the actual values in a rise of temperature of 51.2 deg. cent. The corresponding average value obtained from the results of Professor Clark as reported in his present paper is 46 deg. cent. rise in temperature. Considering the circumstances these resistivity-temperature relations are in fair agreement.

By permission of the American Ceramic Society

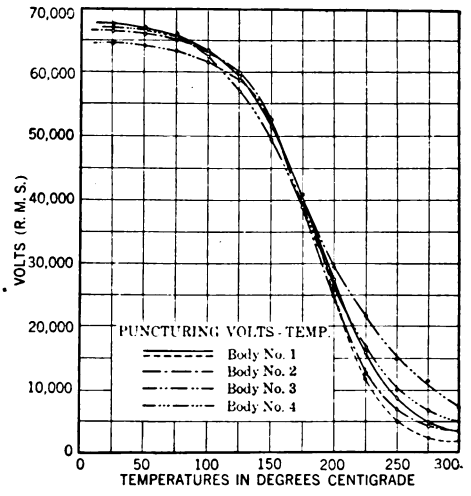


FIG. 6

Weimar and Dunn state that their work "covered that region known as the 'critical temperature' or that temperature at which porcelain ceases to be an insulator and becomes a conductor and to a small extent the effect of composition upon the same." The results obtained are charted in Fig. 6 reproduced from the paper by permission of the American Ceramic Society. The test specimens were cup-shaped 0.15 in. (3.8 mm.) thick heated in an open "electric furnace" and punctured with 60-cycle voltage steadily increased to the rupturing value.

Having in mind the heat resisting duty that porcelain in high-voltage insulators is expected to render when some forms of line "trouble" occur, it is a shock to one when he comes across these

Digitized by Google

results for the first time. Above 300 deg. cent. it was found that the porcelains retained virtually no dielectric strength and that all applied voltage was consumed in setting up current through the test specimen functioning as an electrolytic conductor.

ACKNOWLEDGMENT

The author's study of the service durability of high-voltage suspension insulators would not have been feasible without the advice, helpful discussion and hearty cooperation of the following engineers, Messrs. J. E. Woodbridge, J. P. Jollyman, H. A. Barre and J. A. Koontz.

CONCLUSIONS

1. Appreciably porous porcelain should not be employed for suspension insulators. Under the action of the elements their failure must occur in due course of time.

2. Cement used for setting up cap and pin type suspension insulators should be non-porous or rendered non-porous for reasons set forth.

3. Recognition of porosity as a contributing cause of suspension insulator failures has not lessened the importance of design features that reduce cracking through differential thermal expansions and failure through electrical overstresses and the heat of heavy flash-overs.

4. Defective materials in otherwise well designed and manufactured insulators have been responsible for most of their service-durability failures.

5. Clear fused quartz appears, technically, to be a desirable substitute for porcelain in the construction of suspension insulators.

REFERENCES AND NOTES

1. A. V. Bleininger. The Temperature-Porosity Relations of Clay Prepared in the Plastic and in the Moist Condition. Trans. Am. Ceramic Society, Vol. XV, p. 570, 1913.

2. A. V. Bleininger and R. T. Stull. A Study of the Vitrification Range and Di-Electric Behavior of Some Porcelains. Trans. Am. Ceramic Society, Vol. XII, p. 628, 1910.

3. Entectics formed by Minerals. See p. 79, Vol. XIII, Trans. Am. Ceramic Society, 1911.

4. B. S. Radcliffe. Investigations on Di-Electric Strength of Some Porcelains. Trans. Am. Ceramic Society, Vol. XIV, p. 575, 1912.

5. Ross C. Purdy, Fluxes and Fusion. (President's Address). Trans. Am. Ceramic Society, Vol. XIII, p. 75, 1911.

6. C. E. Henderson and G. O. Weimer. Effect of Temperature on the Di-Electric Strength of Porcelain Insulators. Trans. Am. Ceramic Society, Vol. XIII, p. 469, 1911.

Digitized by Google

7. Trans. Am. Ceramic Society, Vol. XIII, p. 404, 1911. Discussion: "Slow cooling has the same effect in vitrified china as annealing does in glass. If cooled slowly, we obtain a tough body; and if cooled too rapidly a brittle body. While the composition is important, slow cooling is equally as important a factor."

8. An examination of the engineers' records for more than 1000 of each of two lots of well known makes of insulators was made with respect to service durability. One lot had been made and put into service on a 100-kilovolt line, about *eight* years ago. The other lot was ordered, manufactured and delivered and stored in the open *four* years ago. They did not differ, essentially, so far as the author can see, in mechanical-thermal design features. The porcelain in the older lot was of a decidedly finer grain and less absorbent under the ink test than the newer lot. In the first *six* and *one-half* years of service, *one* and *one-half* per cent of the older lot failed. During four years in storage, *twenty* per cent of the newer lot had failed by megger test, or did fail on the application of sixty-cycle spark-over test.

Laboratory experience demonstrates that porcelain insulator bodies are subject to cracking when heated and cooled for the removal of absorbed moisture without hardware attached. For example: Three decidedly porous and water-logged insulators, *B M*4, *B M*30 and *U B*18, were heated slowly in a drying oven to 150 deg. cent. and held there for five hours. The source of heat was then cut off and the oven door opened to allow the insulators to cool. The oven being small, *U B*18, unmounted, had to be taken out when the door was opened. Its rate of cooling was naturally somewhat more than for the others. After being in the open air of the room for a few minutes, it cracked from the edge of the dish to the base of the cap. On close examination, several checks or small cracks in the inner wall of the cap were found, that evidently had occurred earlier. Before drying out, all of these insulators were so water-logged by immersion that they megged so low (a few megohms) that it was known in advance they would not sustain flash-over voltage. After drying out in two stages of about five hours each, the above was the second stage, *B M*4 and *B M*30, mounted insulators, megged with 20,000 volts, continuous, 580 megohms at 11.4 deg. cent., and 3.3 megamegohms at 11.7 deg. cent. respectively. The *B M*30 insulator was then subjected to 60-cycle *spark-over* voltage and endured 20 heavy spark-overs. The *B M*4 insulator has the characteristic of holding on to absorbed moisture tenaciously and must, therefore, be given further oven treatment before the spark-over test should, be applied. (Later, *B M*4 was given another 5 hour treatment in the oven. When cool it megged 1.6 megamegohms, 13.1 deg. cent. it withstood without apparent injury 12 heavy parks-overs at 83 kilovolts, 60 cycles.)

9. E. E. F. Creighton. *Experiences in Testing Porcelain Insulators.* PROCEEDINGS A. I. E. E., Vol. XXXV, p. 865, June 1916.

10. J. Minneman. Note on the Vitrification Range and Di-Electric Behavior of Some Porcelains. Trans. Am. Ceramic Society., Vol. XIII, p. 704, 1911.

11. B. S. Radcliffe. Investigation of Di-Electric Strength of Some Porcelains. Trans. Am. Ceramic Society, Vol. XIV, p. 575, 1912.

Digitized by Google

12. A. Bang. *Four Years' Operating Experience on a High-Tension Transmission Line.* TRANS. A. I. E. E., Vol. XXXIV, Part I, 1243, 1915.

13. George Weimer and C. T. Dunn. The Effect of Temperature on the Di-Electric Strength of Some Porcelains. Trans. Am. Ceramic Society, Vol. XIV p. 280, 1912.

14. The Genesis of Asbestos and Asbestiform Minerals. Stephen Taper, Ph. D. Paper to be presented Feb. 1917 meeting, American Institute of Mining Engineers.

15. "That the toughness of a porcelain is dependent more upon the amount of flint present than upon either of the other two ingredients and that within the limits of this research the percentage of flint to be used for a strong porcelain should be very close to 35. With 35 per cent there seems to be a wide range in variation of clay and feldspar which produces tough bodies." Trans. Am. Ceramic Society, Vol. XIII, p. 395.

16. Vitrified Quartz. Lecture Royal Institution of London. W. A Shenstone, F. R. S., Nature, May 16, 1901.

17. The Effect of Varying the Sizes and Percentages of Quartz Grains upon the Porosities and Shrinkages of Kaolin. S. L. Gaplin. Trans. Am. Ceramic Society, Vol. XII, p. 54.

18. Note on Relation of Porosity and Crushing Strength of Clay Products. A. V. Bleininger. Trans. Am. Ceramic Society, Vol. XII, p. 564

19. Origin of White Residual Kaolins. (President's Address.) Heinrich Rus. Trans. Am. Ceramic Society, Vol. XIII, p. 51.

20. Methods Employed in Connection with the Reduction, Milling and shipment of Quartz, Flint Rock or Silica Sand. Harry F. Speir. Trans. Am. Ceramic Society, Vol. XIII, p. 326.

21. Effect of Composition on the Strength of Porcelains. Lester Ogden. Trans. Am. Ceramic Society, Vol. XIII, p. 395.

22. Melting Point and Deformation of Entectics. Homer F. Stanley. Trans. Am. Ceramic Society, Vol. XIII, p. 668.

23. The Melting points of Pyrotechnic Cones Under Various Conditions. Sam'l. Geijsbeek. Trans. Am. Ceramic Society, Vol. XIV, p. 849.

24. The Relation of the Crushing Strength and Porosities of Clay Products. G. H. Brown. Trans. Am. Ceramic Society, Vol. XIV, p. 292.

25. The Effect of Overburning on the Structure of Clays. A. V. Bleininger and E. T. Montgomery. Trans. Am. Ceramic Society, Vol. XV, p. 71.

26. The Melting Points of Refractory Materials. C. W. Kanolt. Trans. Am. Ceramic Society, Vol. XV, p. 167.

27. The Function of Time in the Vitrification of Clays. G. H. Brown and G. A. Murray. Trans. Am Ceramic Society, Vol. XV, p. 193.

28. The Hydration of Portland Cement. A. A. Klein and A. J. Phillips. Trans. Am. Ceramic Society, Vol. XVI, p. 313.

29. The Legal definition of Vitrification. Edward Orton Jr. Sec'ty. Am. Ceramic Society, Trans. Am. Ceramic Society, Vol. XVI, p. 497.

30. Ceramics. The Constitution and Microstructure of Porcelain, by A. A. Klein, Bureau of Standards. (Summary communicated by the director of the Bureau of Standards, Dr. S. W. Stratton, details to appear as Bureau of Standards Technologic Paper No. 80) Journal of the Washington Academy of Science, Vol. VI, page 658, November 19, 1916.

Digitized by Google

Presented at a section meeting of the American Institute of Electrical Engineers, San Francisco, Cal., November 24, 1916.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

EXPERIMENTS ON PORCELAIN SUSPENSION INSULATOR UNITS

BY J. CAMERON CLARK

ABSTRACT OF PAPER

The author gives a very complete description of the experiments on porcelain suspension insulator units carried on at Stanford University by him and his assistants under the direction of Prof. H. J. Ryan. He explains the preliminary organization necessary, the scope of the tests, and the unusual equipment required to measure the very high resistance of sound, dry insulators. Preliminary resistance measurements were made on all normal batches of porcelain units and the results tabulated, as also were results obtained when the units were subjected to mechanical stress, to voltages ranging from 1,000 to 30,000, to temperature variation. Another set of tests was made to determine the effect of moisture in insulators. Drying insulators for a few hours in an oven at 150 deg. cent. produced very conclusive results of the effect of moisture in lowering resistance. Attempts were made to water-log units by soaking, by soaking with a temperature cycle applied, by subjecting units under various conditions to a steam pressure of 60 lb., and by a vacuum treatment of insulators before soaking. A brief statement is given of the conclusions arrived at.

INTRODUCTION, ORIGIN OF, AND ORGANIZATION FOR THE WORK

THE WORK of Prof. Ryan. The work of Prof. Harris J. Ryan at Stanford University in the winter of 1915-16 demonstrated both the feasibility and the desirability of measuring the insulation resistance of suspension insulator units having resistances in the range between 5000 megohms and several millions of megohms. To illustrate: It was shown by Prof. Ryan that certain units having insulation resistances of, say, 15,000 megohms could be punctured in the air on 60-cycle voltage. The ordinary portable megger of 5000-megohms maximum scale reading will give a reading of infinity for such a unit, as it is unable to differentiate between units of 6000 and 1,000,000 megohms, whereas a dry, sound porcelain insulator will have a resistance of the order of 1,000,000 megohms or one "megameg-

Manuscript of this paper was received November 21, 1916.

*These values, as well as all other resistance values contained in this paper, are referred to a temperature of 20 deg. cent. unless otherwise mentioned.

Digitized by Google

ohm". Prof. Ryan also disclosed the fact that some units become much lower in insulation resistance when subjected to prolonged soaking in water.

Organization for tests. This work stimulated much thought among high-voltage engineers and, in particular, it aided in crystallizing a desire among them to develop a method by which it would be possible to detect faulty units with certainty, thus rendering it possible to avoid their installation. Accordingly, a committee of engineers was formed in May, 1916 to undertake experimental investigations of suspension insulator units, having as their broad purpose the production of test methods by which to detect with certainty and celerity all units which are electrically weak. Obviously, there is much difference of opinion on the classification of insulators as electrically "weak" and "strong". It is held by the committee, however, that any unit which is either weak at time of test or gives any indication whatever of the capability of developing weakness through lapse of time is to be condemned as weak.

The financial support of the work has consisted in contributions from a number of the California power companies. These companies, besides certain insulator manufacturers, have contributed liberally in test-specimens which will be found illustrated and briefly described in connection with "Preliminary Resistance Measurements".

The facilities of the electrical laboratories of Stanford University were placed at the disposal of the committee during the three summer vacation months of June, July, and August, 1916; and the writer and assistants were employed during this period to prosecute the testing work.

Experimental Work

Scope of Tests. In addition to the measurement of the insulation resistance of every insulator unit in the condition in which it arrived at the laboratory, the summer's work consisted largely in attempting to determine the influence of certain important physical conditions of the insulator units upon their insulation resistance. The physical conditions which have been thus investigated are; mechanical stress, electrical stress (using continuous voltage), temperature, absorbed moisture.

The High-Voltage Megger. Since the resistance of a sound, dry porcelain insulator at ordinary air temperature is exceedingly large (of the order of 10^{12} ohms), it became necessary to provide

Digitized by Google

rather unusual equipment with which to measure this quantity. Without entering into a discussion of the possible apparatus for this purpose, it may suffice to say here that it was decided to employ 25,000 volts continuous pressure current through the insulator, and to use as sensitive a D'Arsonval type galvanometer as could be had conveniently, to measure the current.

The pieces of apparatus which, taken collectively, may be called the high-voltage megger are shown diagrammatically in Fig. 1. T_1 is a 33-kv. transformer which supplies charge to the air condenser C, at high voltage through the kenotron K. T_2 is an insulating transformer through which the heating current is furnished to the cathode filament of the kenotron. The contin-

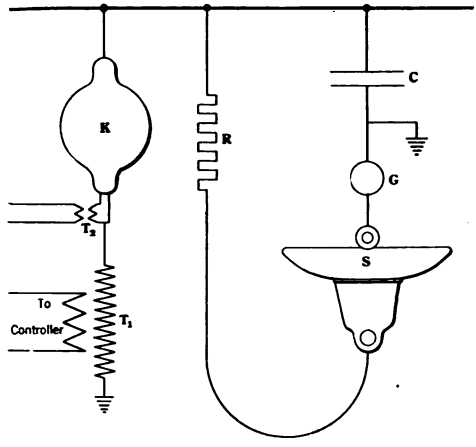


FIG. 1—HIGH VOLTAGE MEGGER—CONNECTION DIAGRAM

uous high voltage is impressed upon the insulator at S through the resistance R which is provided as a protection to the kenotron against a possible short-circuit of the load at S. R is adjusted to allow only full-load current for the kenotron to flow on such a short-circuit, and with 25,000 volts on the circuit. The galvanometer G is connected in the test circuit next to ground. The connections from the low-voltage side of the insulator to the galvanometer are described in detail below.

The use of 25,000 volts on the insulator results in an amount of surface leakage vastly in excess of that which occurs with the 600 to 1000 volts ordinarily used in megger tests. Most of this leakage is in the form of corona, and hence cannot be eliminated by any amount of careful cleaning of the surface of the insulator.

Digitized by Google

It is accordingly necessary to conduct all such strays directly off to ground by a path around the galvanometer. Fig. 2 shows the scheme used. Whenever possible, ordinary tap-water is used to make connection to uncemented porcelain blanks, and to make guard-rings, as it is very convenient in application. With units unprovided with petticoats, a felt ring saturated with water is laid on as a guard-ring, and the can guard is set directly on top of this felt ring. A grounded lead sheath protects the entire length of the wire running from insulator to galvanometer, while the instrument is remote enough from the high-voltage parts of the circuit to be immune from stray currents through the atmosphere.

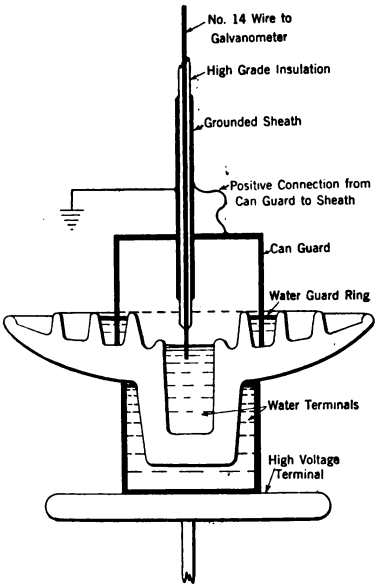


FIG 2—DETAILS OF GUARDING SCHEME

Adjustment of the megger voltage is secured by means of an auto-transformer with multi-gap secondary feeding through a controller into the primary of the 33-kv. transformer, while a voltmeter connected across this primary serves to determine the megger voltage, a calibration curve of the megger in terms of the primary voltage having been secured by means of a 7-inch (17.7-cm.) sphere gap.

Preliminary Resistance Measurements. Table I is a summary of the resistance measurements made on all of the normal batches of porcelain units immediately upon their arrival at the laboratory. The *UK* units are uncemented blanks of the same make and year as the assembled units of the *J* series. The *U H* units are blanks corresponding in every way to those used in the assembled *H* units. The photographic reproductions, Figs. 3 to 10 inclusive, illustrate all the types of units listed in the table. Table I also contains letters designating which insulator units are from a common maker. To illustrate: Units *G*, *H*, and *H M* were all made by the same manufacturer, *C*. It will thus be seen that the porcelain products of four different makers, *A*, *B*, *C*, and *D* are represented in the tests.

Digitized by Google

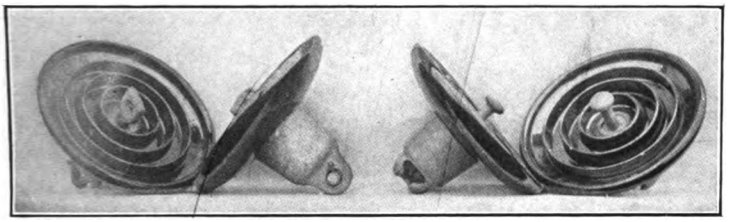


FIG. 3 FIG. 4

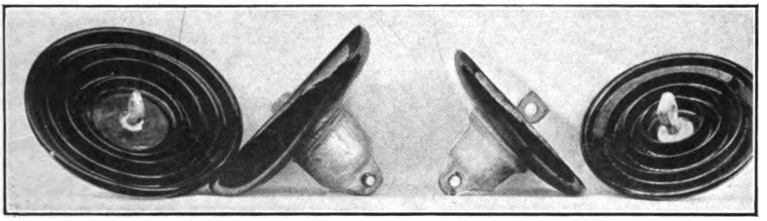


FIG. 6 FIG. 5

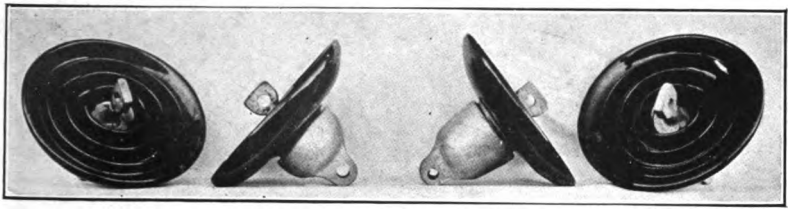


FIG. 7 FIG. 8

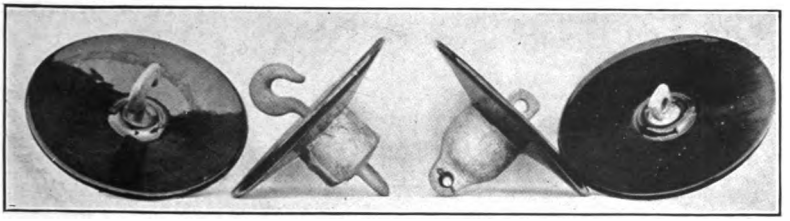


FIG. 9 FIG. 10

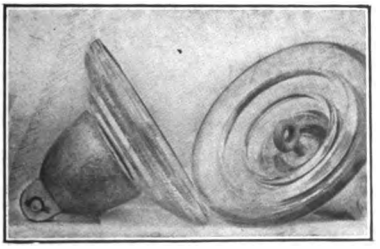


FIG. 13

Digitized by Google

Digitized by Google

TABLE I.

MEGAMEGOHM CLASSIFICATION OF PORCELAIN INSULATOR UNITS

(Compiled from insulator resistance measurements made on units as they were first received.)

Series	*A*	1 *A*-13 *A*	*C*	*J*	*U K*	*B*	*B L*	*G*	*H* and *UH*	*H M*	Q_1	Q_2
Figure	3	3	3	5	5	4	4	9	10	6	7	8
Maker	*A*	*A*	*A*	*A*	*A*	*B*	*B*	*C*	*C*	*C*	*D*	*D*
Date of manufacture	1912	1912	1913	1916	1916	1916	1913	1908	1916	1915	1916	1916
Megamegohm classes												
Below 0.010	..	1	..	..	..	..	3	..	..	..	..	..
0.010–0.099	..	3	..	1	..	..	..	..	..	..	..	..
0.10 –0.19	..	..	..	..	..	..	..	..	..	1	1	..
0.20 –0.39	1	1	5	2	..	..	1	..	54	9	..	..
0.40 –0.59	1	3	5	..	..	8	..	..	37	..	..	1
0.60 –0.79	2	32	17	1	4	90	..	..	3	1	1	40
0.80 –0.99	48	29	33	7	4	7	1	1	..	2	1	7
1.00 –1.19	40	20	12	51	4	..	8	5	3	8	28	..
1.20 –1.39	7	8	17	33	4	..	39	4	3	13	17	..
1.40 –1.59	3	2	..	22	..	..	31	4	..	2	1	..
1.60 –1.79	..	1	..	5	..	..	7	29	..	1	..	..
1.80 –1.99	..	..	..	1	..	..	11	33	..	1	..	..
2.00 –2.19	..	1	..	1	..	..	4	14	..	..	..	..
2.20 –2.39	..	..	..	..	..	..	1	7	..	..	..	..
2.40 –2.59	..	..	..	..	..	..	..	3	..	..	..	..
Total	102	101	89	124	16	105	106	100	100	38	49	48

Digitized by Google

In addition to the units of Table I, reference is made in this paper to various members of three additional small groups of units; namely, the *U B*, *B M*, and *F* groups. Of these the *U B* and *B M* units are specially selected soggy specimens of the same make and date as the *B L* series of Table I. The *F* units are of a new material, not porcelain. Fig. 11 shows the temperature-resistance characteristic of this material as exhibited by unit *F* 5. Fig. 13 is a photograph of an *F* unit.

Pull-Resistance Studies. A testing machine was used to subject the units to mechanical stress to detemine whether this would affect their resistance. Pulls ranging from 0 to 5000 lbs. (22679. kg.) were applied to each kind of unit, but in no case was there any change in resistance from that obtaining for the unit in the mechanically unstressed condition.

Voltage-Resistance Studies. Some work was done using the high-voltage megger to ascertain whether the resistance of a unit is constant over the range 1000 to 30,000 volts. In any case where this source has been used, there has appeared to be practically no variation in insulation resistance over the range mentioned. However, some earlier work was done in the megging of very soggy units in which continuous voltages below 750 volts were used in order to hold the galvanometer current down to safe values. In every case where such a unit was later megged on 25,000 volts, the resistance thus determined is much lower than that obtained on the lower voltage. Table II shows results thus secured.

TABLE II

Unit No.	Test Voltage	Resistance, megohms
B L 19	110	13,000
	25,000	820
5 *A* 6	415	21,000
	25,000	6,900
B L 105	625	13,000
	25,000	8,300
B L 68	635	8,300
	25,000	2,200
8 *A* 4	730	60,000
	25,000	20,000
8 *A* 2	740	73,000
	25,000	42,000

Digitized by Google

It is not clear why there should be a difference between the resistance values obtained for these units at low voltage and at high voltage since quite a variety of low- and high-resistance units tested over a range of 1000 to 30,000 volts have shown no variation of resistance over that range.

Temperature-Resistance Studies. Early in the work it was brought forcibly to the attention of the test force that the temperature of an insulator is a factor of the greatest importance in its behavior under the megger test. To illustrate this point, Table III is presented.

TABLE III.

Unit No.	Resistance as first measured, megamegohms	Resistance as later measured, 20 deg. cent. megamegohms
1 A 3	1.25	1.03
1 A 4	1.04	0.99
1 A 5	1.09	1.12
1 A 6	0.93	1.09
1 A 7	0.60	0.74
1 A 8	2.08	1.01
2 A 1	0.83	1.11

The second column gives results which were obtained before the influence of temperature upon the resistance of an insulator was fully appreciated. The units had been lying in the hot sun for about an hour for the purpose of drying following a washing which had been given them. They had then been brought into the laboratory and laid on the floor for various lengths of time ranging from 15 to 45 minutes before being megged. It was then assumed that the room temperature (25 deg. cent.) could be taken as the temperature of the units without much error. The third column gives later results obtained after the units had reached a carefully determined steady temperature of 20 deg. cent. The lack of concord between the results in the second and third columns shows clearly the necessity for more careful work in this respect and, together with other similar observations, indicated the need of making a rather careful study of the resistance of porcelain as a function of temperature. An oven was therefore constructed which makes it possible to heat up eight units simultaneously and to megg them conveniently one after another on 25,000 volts continuous. All units rest on a common grate upon which is impressed the high voltage. Eight low voltage

Digitized by Google

connections pass out through the thick heat-insulated wall of the oven to a terminal board at which the galvanometer lead is connected to any unit desired. The temperature is determined by 10 carefully calibrated resistance coils wound of No. 34 copper wire having heavy leads brought out for convenient connection to a Wheatstone's bridge. The coils are placed at the height of the porcelain of the units and are otherwise at locations so

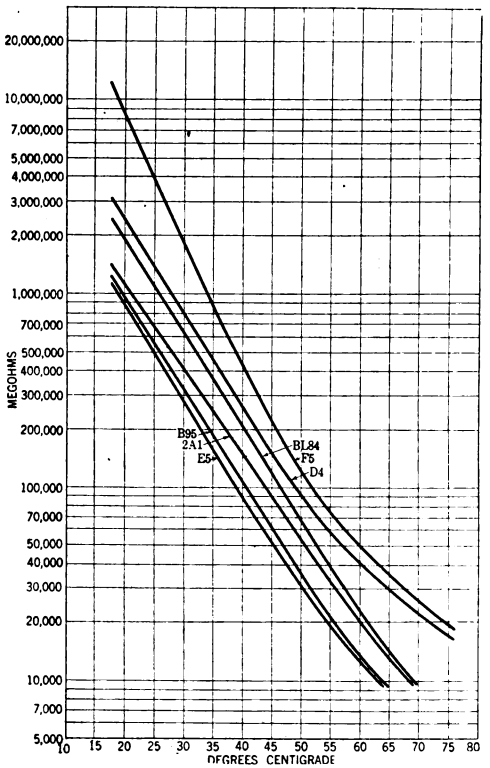


FIG. 11—VARIATION OF RESISTANCE WITH TEMPERATURE

chosen within the oven as to make it possible to judge of the resistance of a unit with a precision ranging from 0.2 deg. cent. at 25 deg. to 1 deg. at 65 deg.

The results of the study of six different insulator units are shown in the curves of Fig. 11. An exceedingly rapid rate of decrease of resistance with increasing temperature is shown by all the units, and this rate is substantially the same for all the different makes of porcelain insulators investigated. Fig. 12 is

Digitized by Google

a curve derived from the temperature resistance curves of porcelain units which has been found very useful in reducing to a common temperature basis of 20 deg. cent. resistance measurements made over a temperature range of 17 to 27 deg. cent.

Moisture in Insulators

Results of Drying Out Insulators. That some high-voltage porcelain absorbs enough moisture to lower its resistance is shown conclusively by the results of drying numerous insulator units for a few hours in an oven at 150 deg. cent. All the insu-

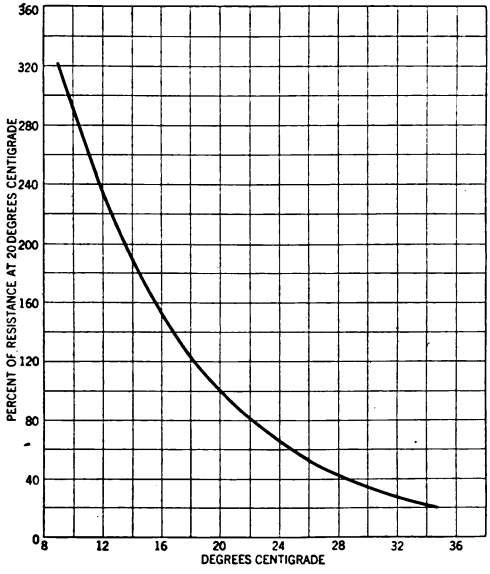


Fig. 12—Porcelain Insulator Temperature Reduction Curve

lators investigated in this way fall naturally into three classes (see Table IV) as determined by the effect of the drying upon their resistance; viz., (a) those practically unaffected by any amount of drying, (b) those raised in resistance by 20 to 400 per cent, (c) those enormously raised in resistance, *i.e.*, hundreds or thousands of times. A result of this natural division of the units has been for the test force to call classes (a), (b), and (c) respectively "non-porous", " slightly porous", and "very porous".

Attempts to Water-log Units. It is obvious that a very easy laboratory test for the detection of porosity in an insulator is the high-voltage megger test, *provided the insulator is already water*

Digitized by Google

TABLE IV.
RESULTS OF DRYING INSULATORS AT 150 C.

Class (a)			Class (b)			Class (c)		
Unit No.	Total hours drying	Megohms	Unit No.	Total hours drying	Megohms	Unit No.	Total hours drying	Megohms
B 56	0	700,000	*A* 29	0	220,000	*B M* 4	0	42
	6	750,000		5	1,180,00		7	1,470,000
B 69	0	690,000	*B L* 18	0	390,000	*B M* 30	0	2
	7	700,000		5	1,390,000		3	15,700
G 9	0	1,770,000	*U K* 12	0	730,000		5½	130,000
	8	1,790,000		7½	990,000		15	720,000
H 4	0	300,000	*G* 50	0	1,160,000		33	1,550,000
	6½	320,000		6½	1,610,000		43	1,670,000
U H 37	0	300,000	*G* 50	0	1,300,000	*U B* 14	0	2,080
	6	320,000		6½	1,720,000		4	770,000
U H 79	0	320,000	*G* 81	0	730,000	5 *A* 6	0	6,800
	7	320,000		6	1,610,000		7	1,130,000
U K 14	0	1,000,000	*G* 71	0	1,080,000			
	6½	950,000		6½	1,870,000			

Digitized by Google

logged. However, many, if not all, very soggy units (*i.e.*, units reading below infinity on the 5000-megohm megger) may be raised by a few hours drying to an apparently perfect condition in which they pass a 60-cycle dry spark-over test in air. It has accordingly been regarded as essential that a method be found by which porous units may be made to take up water quickly inasmuch as any test which consumes weeks or months of time in order to establish porosity cannot be considered to have practical or commercial value.

Early in the work, the soaking of porcelain units in water at ordinary atmospheric temperatures was undertaken, but it became evident that, by this method, water enters wet-process porcelain units with extreme slowness, even in the case of units which have been called in the laboratory, "very porous".

It was then suggested that, along with the soaking, a temperature cycle be applied. It was the idea that there might exist a sort of breathing action caused by volumetric changes of the material under changing temperatures which would draw water into the extremely attenuated pores of the porcelain. Accordingly, five units which were believed to have varying degrees of porosity were selected and put through the following cycle; Put into tub of water and water brought from 30 deg. cent. to boiling, 1 hour; water being boiled, ½ hour; water being cooled to 30 deg. 1 hour, units cooled in "cold tank", (20 deg. cent.), ½ hour. This cycle was repeated two or three times per day. The results are shown in Table V:

TABLE V.

"ACCELERATED SOAKING"—RESISTANCES IN MEGAMEGOHMS.

Total cycles	*U B* 3	*U B* 5	*U B* 13	*U B* 14	*U K* 13
0	0.75	0.73	0.0085	0.53	0.80
1	0.55	0.41	0.011	0.36	0.62
2	0.66	0.57	0.030	0.39	0.80
3	0.61	0.55	0.021	0.36	0.76
5	0.66	0.84	0.046	0.36	1.27

As shown by the table, the only positive effect of this process was to raise the resistance of some of the units treated. This is no doubt due to a rapid driving out of water from the porcelain during the boiling part of the cycle.

Another "accelerated soaking" test was next attempted in which the boiling part of the cycle was eliminated, the water being carried to a maximum temperature of 75 deg. cent. The

Digitized by Google

same five units used in the previous test were subjected to this modified test. The results are shown in Table VI.

TABLE VI.

MODIFIED ACCELERATED SOAKING—RESISTANCES IN MEGAMEGOHMS.

Total cycles	*U B* 3	*U B* 5	*U B* 13	*U B* 14	*U K* 13
0	0.82	0.72	0.032	0.34	0.99
5	0.76	0.65	0.0039	0.18	1.01
8	0.71	0.63	0.0021	0.115	0.98
16	0.72	0.65	0.0011	0.072	0.94
24	0.82	0.66	0.00074	0.025	0.99

It is seen from Table VI that the rather porous units *U B* 13 and *U B* 14 are rapidly brought down in resistance by the 24 cycles of treatment, but that the slightly porous unit *U K* 13 has not been affected at all.

It was suggested that the entry of water into the pores of porcelain might be expedited by keeping one side of the porcelain exposed to the atmosphere while water is applied to the other, it being the theory that the application of water to both sides of the unit traps a certain amount of air within the pores effectually preventing the entire filling of the pores with water. To test this theory, two very porous units were selected and water was applied to one side of each. With a cemented unit, *B M* 30, the insulator was inverted and water was simply poured around the pin within the inner skirt of the unit and allowed to remain there for about two weeks. In the case of the other unit, *U B* 18, which is an uncemented porcelain blank, a rig was devised by which the pin cavity was filled with water and kept under 60 lb. per sq. inch (4.2 kg. per sq. cm.) pressure for about 30 hours. In neither case was there any material acceleration of the water absorption beyond that which would occur with ordinary soaking of the entire unit in water.

Since the negative results obtained in the application of water to one side of porcelain units may imply that the pores of the material are of such minute section that water enters them rapidly when in gaseous form, it was concluded to try the application of steam to one side of a porous unit. The test rig mentioned in the previous paragraph was therefore modified to permit the unit to be heated from the outside hot enough to generate steam within the pin cavity while the latter is kept filled with water at 60 lb. per square inch pressure. Thus steam at 60 lb. (27.2 kg.) pressure is applied to the inner surface of the pin cavity. Unit *U B* 18 was given two hours of this steam treatment. Megohm

Digitized by Google

readings taken just before the test, and again as soon afterward as the unit had become cold are respectively 310,000 and 1050. This shows a remarkably rapid lowering of the resistance. This test was also applied to unit *U K* 13 which had been considered to be a slightly porous unit from the results of the first "accelerated soaking" test, see Table V. However, megger readings taken just before three hours treatment of the unit and afterward as soon as the unit had become cold show in each case a resistance of 0.85 megamegohms.

Vacuum treatment just before soaking has been tried with a number of units believed to be of varying degrees of porosity. The results of one such test are shown in Table VII.

TABLE VII.

VACUUM AND PRESSURE TREATMENT—RESISTANCES IN MEGAMEGOHMS.

Unit No.	Resistance in megamegohms			Remarks on previous status of unit.
	Aug. 16	Aug. 17	Aug. 18	
U B 2	0.00052	0.00028	0.00019	Considered "very porous" because of rapid lowering of its resistance in cold water soaking.
C 76	0.123	0.0101	0.0029	Considered "very porous" because its resistance lowered rapidly when stored on concrete floor in a cool place.
C 1	0.79	0.94	1.00	Considered "slightly porous" as its resistance rose decidedly when stored in a warm, dry place.
G 50	1.69	1.61	1.74	Considered "slightly porous" because its resistance rose somewhat due to drying in oven.
G 60	1.69	1.79	1.63	Same as *G* 50
G 71	1.69	1.50	1.61	Same as *G* 50
G 81	1.51	1.45	1.42	Same as *G* 50.

The values of resistance for Aug. 16 were obtained just prior to placing the units in the vacuum tank. On Aug 16, the units were put under a 25-inch (63.5 mm.) vacuum for $1\frac{1}{2}$ hours, and while the vacuum was maintained, water was run into the tank until the units were covered. The water was allowed to remain over the units at atmospheric pressure over night (15 hours), and the results for Aug. 17 were then obtained. A 25-inch vacuum was again applied to all the units for five hours which was followed up immediately by water, the vacuum being maintained until the tank was filled with water. The water was kept under the supply pressure of 60 lb. per sq. inch above atmosphere over night ($14\frac{1}{2}$ hours), and the values of Aug. 18 were then obtained. As shown by the table, decided lowering of resistance occurred only in the cases of the "very porous" units.

Digitized by Google

With but two exceptions, the methods which have been tried in attempting to water-log units rapidly have been fairly successful in the cases of units known to be very porous. These two exceptions are the ordinary soaking in cold water and the attempt to accelerate water-logging by heating and cooling wherein boiling occurred during the cycle. However, no method has yet been found by which the slightly porous units can be made to take water rapidly. That efforts to this end have failed is remarkable in view of the fact that the water may be driven out of such units in a very few hours by heating them at 150 deg. cent. Whether these insulators would deteriorate in actual line service is a debatable question, the discussion of which lies outside the scope of this paper.

Conclusion

Much of the work of the summer has been concerned with the study of moisture absorption in porcelain insulators as indicated by their insulation resistance. This is largely due to the fact that few other characteristics of the specimens submitted have seemed so much worth while investigating as their porosity. In this connection, it is important to note that very little trouble with cracking due to expansion of metal parts is in evidence among the specimens, even among the older batches of units wherein little attention was evidently given to this subject. Some 60 assembled units of various makes have been subjected to temperatures ranging from 110 deg. to 150 deg. cent.—much higher temperatures than are ever encountered in service. Among these units were 30 selected as being most likely to crack owing to bad design wherein no provision was made at the base of the cap next to the disk for expansion of the cap. Out of the 60, only 3 units have failed by cracking; namely, Nos. *B L* 94, *C* 9, and *C* 76,— all of old design.

Inasmuch as the real factors which contribute to the weakness of many porcelain insulators are now much better appreciated, it is felt that some progress has been made toward achieving the broad purpose of the investigation; namely, to develop ready, sure and simple methods by which to detect the weak insulator. It is at the same time realized that a great amount of work remains to be done, and it is hoped that many others will devote themselves to this problem which it seems so necessary to solve if confidence is to attend the continued use of the porcelain high-voltage insulator.

Digitized by Google

Presented at a section meeting of the American Institute of Electrical Engineers, Denver, Colo., February 19, 1916.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

THE FUTURE OF WATER POWER IN THE UNITED STATES

BY CHARLES W. COMSTOCK

ABSTRACT OF PAPER

This paper gives a careful compilation of figures showing the total fixed installed primary power in the United States and similar figures for total installed water power, at the same time calling attention to the unreliability of statistics in general. With these figures, those compiled by the Commissioner of Corporation are summarized and compared.

The geographic distribution of installed water power is considered and many interesting facts revealed when these figures are examined from the viewpoint of population distribution. A study of the development of water power between 1889 and 1909 shows some interesting differences as compared with distribution of manufacturing power and total developed water power.

The author next takes up the question of the possibilities of water power development and points out the fallacy of power development waiting upon demand instead of creating it. The immense field for hydroelectric power which a development of the electro-chemical and electro-metallurgical industries would create with the success of such industries abroad is cited and an appeal made for a Federal policy of encouraging business enterprise instead of obstructing it.

IN PRESENTING this paper before an organization of electrical engineers, I wish to say by way of preface that it is not electrical, nor yet engineering. It is, if anything, economic; in some degree comparative, and slightly statistical. Having in mind Disraeli's classification of untruths as "lies, damned lies, and statistics," you may know what to expect.

In order to get ourselves properly oriented, as the surveyors say, it is well to take a bird's-eye view of the entire power field. The total fixed installed primary power in the United States, as given by the Census Bureau, is as follows:

The unit is the horse power.

Commercial and municipal central electric stations, 1912	7,528,648
Street and electric railways, 1912	3,665,051
Steam road electrification, 1912	193,956
Total electric installations	11,387,655
Manufacturing, 1909	16,802,706
Mines and quarries, 1909	4,402,554
Total fixed installed primary power	32,592,915

Manuscript of this paper was received March 7, 1916.

Digitized by Google

The Census Bureau has a disconcerting practise of collecting some of its data as of the years ending with two and seven, while other information is gathered for the years ending with four and nine. Our figures are, therefore, out of phase, the electric power data leading by 216 degrees, and we are not strictly within our rights in making these numerical additions, but the results will serve our purposes for general comparisons.

The figures here given for manufacturing and for mines and quarries are exclusive of nearly two million horse power classed as rented power, which is included under the central electric stations. No account is taken of the power installed in isolated plants, such as hotels, large mercantile establishments, office buildings and the like. The aggregate of these must be very large, but they have not been included in census returns, and no list of them is believed to exist.

In addition to the fixed power, consideration must be given to the power generated by steam locomotives. There are in the United States about 65,000 locomotives in service. It would be absolutely meaningless to add their rated horse power, even if it were obtainable. Doubtless it exceeds the total fixed power of the country. We can, however, by an indirect method, approximate its equivalent in fixed power. In the year ending June 30, 1914, the railroads of the country expended, in round numbers, $242,000,000 for locomotive fuel. A small portion of this fuel was oil, but far the larger part was soft coal. If the average price of this coal be assumed at $2.00 per ton, the locomotives burned 121,000,000 tons (1 long ton = 1.01 metric ton) of coal during the year. Allowing 26 tons per h.p-year (about six pounds (2.7 kg.) per h.p-hr.), the equivalent continuous output is 4,692,000 h.p., or, with a 60 per cent load factor, 7,820,000 h.p. If all the railroads in the country were electrified, the necessary installed power for their operation would probably not be far from this latter figure, although, of course, the total coal consumption would not exceed one-third that used under the present system. The fixed installation, in these circumstances, would then be about 120 h.p. per locomotive in service.

The data are not available with which to estimate the power used in navigation, and the inquiry would not be pertinent in this connection, even if we could make the estimate.

We have, then, at the present time in the United States the equivalent of at least forty million horse power in fixed installations, without counting the isolated plants already mentioned,

Digitized by Google

which must total a very large amount, though we have no basis for an intelligent guess.

How much of this is water power? From the census reports again, we have the following:

Commercial and municipal central electric stations, 1912	2,471,081 h.p.
Street and electric railways, 1912	471,307 "
Steam road electrification, 1912	8,000 "
Total hydroelectric installations	2,950,388 "
Manufacturing, 1909	1,822,888 "
Mines and quarries, 1909	97,460 "
Total installed water power	4,870,736 "

The installed water power is, therefore, 14.94 per cent of the total fixed primary power, or about 12 per cent of all power, including locomotives.

In 1908 the Census Bureau reported to the National Conservation Commission that the developed water power of the country aggregated 5,356,680 h.p., of which 3,396,103 h.p. represented developments not less than 1000 h.p., and 1,960,577 h.p. were smaller developments. These figures, however, were not limited to actual installations, but included many power sites only partially developed, or, to quote exactly, "undeveloped power sites upon which some expenditure had been made."

In a report to the Secretary of Commerce and Labor, dated March 14, 1912, the Commissioner of Corporations stated the developed water power in plants of 1000 h.p. or more, to be 4,016,127 h.p. of which 2,961,549 was classed as commercial and 1,054,578 as manufacturing. These figures are of date June, 1911. The difference of nearly 800,000 h.p. between this estimate of manufacturing power and the census figures of 1909 is probably to be accounted for by small manufacturing plants. To the figures above given, the Commissioner adds 2,000,000 for plants of less than 1000 h.p., making "a grand total, in round numbers, of at least 6,000,000 h.p. as the total water power of the United States, developed and under construction in June, 1911."

A still further addition of 2,638,528 h.p. is made by the Commissioner to cover "the undeveloped power owned or controlled by the concerns reporting developed power." This report of the Commissioner of Corporations may be summarized as follows:

Digitized by Google

Concerns having 1000 h.p. or more:

Commercial	2,961,549 h.p.
Manufacturing	1,054,578 "
Undeveloped	2,638,528 "
Total	6,654,655 "
Plants of less than 1000 h.p., about	2,000,000 "
Grand Total	8,654,655 "

This appears to be the only basis for the inaccurate statement made by Mr. George Otis Smith, Director United States Geological Survey, in an address delivered before the Second Pan-American Scientific Congress, on December 28, 1915, that "the present installation of water power plants in the United States is estimated at 8,500,000 h.p." There is an obvious difference between an installed plant and the mere ownership or control of a site. I know of several power sites whose owners are looking anxiously for someone to help them let go of the bear's tail. No doubt it was such misuse of data that prompted Disraeli to place statistics in the next place beyond the damned lie.

Taking into account the fixed power-equivalent of steam locomotives, and the certainly large, though unknown, amount of power in isolated plants, it is probably safe to say that the actual water power installations of the United States aggregate not far from 10 per cent of the total installed primary power.

The next point of interest is the geographic distribution of the installed water power. This is shown in the following table:

GEOGRAPHIC DISTRIBUTION OF WATER POWER

	Manufacturing, 1909	Central electric stations, 1912	Electric railways 1912	Total
	%	%	%	%
New England	41.5	7.4	7.4	20.9
Middle Atlantic	25.7	26.8	4.1	24.0
East North Central	11.4	10.0	8.9	10.8
West North Central	4.8	4.1	4.7	4.3
South Atlantic	10.1	14.1	13.6	12.4
East South Central	1.6	1.5	0	1.3
West South Central	0.2	0.2	0	0.2
Mountain	1.2	12.9	4.5	7.4
Pacific	3.5	23.0	56.8	18.7
	100.0	100.0	100.0	100.0

The distribution of the power used in mining and quarrying could not be learned, but the total quantity so consumed is small, and, whatever its distribution, can not sensibly affect these figures.

Digitized by Google

An examination of this table reveals several interesting facts. One-half the population of the United States is east of the western boundary of Ohio; sixty per cent of the developed water power is east of that meridian. One-half the population is north of the parallel of Denver; seventy-five per cent of the developed water power is north of the same line.

The Atlantic coast states, from Maine to Florida, contain 57 per cent of the developed water power and 41.3 per cent of the population. The states west of the eastern boundaries of New Mexico, Colorado, Wyoming, and Montana contain 26 per cent of the developed water power and 7.5 per cent of the population. The great Mississippi valley region, from Canada to the Gulf of Mexico and from Pennsylvania to Colorado, contains rather less than 17 per cent of the developed water power, with 51.2 per cent of the population. The three Pacific coast states alone contain 18.7 per cent of the developed water power, but only 4.6 per cent of the population.

As we shall see later, all this has a bearing on the alarmist talk about water power monopoly with which we are regaled from time to time by Young-man-afraid-of-his-job or some other member of a Federal bureau, the sole purpose of whose existence is to seek out the unfortunate private citizen who has more than three dollars, and regulate him. With these gentry it is a case of "Johnny, go out and see what Willie is doing, and tell him to stop it."

The general character of the evolution in the development and use of water power is familiar to all. The first water wheels were installed to drive grist mills, saw mills and other plants whose activities were directly connected with the every-day necessities of the people. Naturally these were in the New England states. As the population increased and its requirements became less primitive, the power sites were further developed and applied to paper manufacture, the textile industries and the like. Even today 41.5 per cent of the water power devoted to manufacturing, as distinguished from that generated in central stations and sold for general commercial purposes, is located in New England, and 67.2 per cent is in New England, New York, New Jersey and Pennsylvania. Nearly all the remainder is in the South Atlantic states and in the states north of the Ohio and east of the Mississippi river.

The water power thus directly applied to manufacturing industries has not increased very rapidly for the past twenty years,

Digitized by Google

and the growth is likely to be even less important in the future. In 1889 the water power so applied aggregated 1,255,045 h.p.; in 1899—1,454,112 h.p.; in 1909—1,822,888 h.p. The increase was thus 15.9 per cent from 1889 to 1899, 25.4 per cent from 1899 to 1909, and 45.2 per cent from 1889 to 1909. For the same periods the total power used in manufacturing increased from 5,938,635 h.p. in 1889 to 10,097,893 in 1899, or 70 per cent and to 18,675,376 h.p. in 1909, an increase of 85 per cent since 1899, and of 214 per cent since 1889.

The North Atlantic states became important manufacturing centers because of readily accessible and easily developed water powers. Large populations grew up around them and these people in turn constituted a market for the manufactured products. Thus, this region had three of the four requisites for a successful manufacturing country, viz: cheap power, ample labor, and a near-by market. These advantages it still has to a considerable extent, though the first it is rapidly losing.

In the early nineties, hydroelectric development began in earnest. The first Niagara plant (55,000 h.p.) about 1894, was the first important installation of this character. In 1902 the aggregate of the hydroelectric developments of the United States was 438,472 h.p. in central station installations, and 49,153 h.p. in electric railway plants, a total of 487,625 h.p. In 1907 these had increased to 1,349,087 h.p. in central stations, and 91,961 h.p. in electric railway plants, a total of 1,441,048 h.p. or nearly as much as the total installed water power for manufacturing purposes. In 1912 the central station installations had become 2,471,081 h.p. and the electric railway plants 471,307, h.p. a total of 2,942,388 h.p., or 61 per cent more than all the installed manufacturing water power. The increase in hydroelectric installations was 195.5 per cent from 1902 to 1907, 104.2 per cent from 1907 to 1912, and 502 per cent from 1902 to 1912. The proportionate increase in ten years, ending 1912, was more than eleven times the proportionate increase in manufacturing water power in twenty years ending 1909.

A study of the distribution of the development shows some interesting differences as compared with the distribution of manufacturing power and of total developed water power.

New England has only about 8 per cent of the hydroelectric as against more than 40 per cent of the manufacturing power. The north Atlantic states, including New England, have about 30 per cent of the hydroelectric and nearly 70 per cent of the

Digitized by Google

manufacturing power. The eastern half of the population has only 45 per cent of the hydroelectric with 60 per cent of the total developed water power. The northern half of the population has about 70 per cent of the hydroelectric development.

The Atlantic coast states have 45 per cent of the hydroelectric development, and a little more than 41 per cent of the population. The states between Pennsylvania and Colorado have more than one-half the population, but only 16 per cent of the hydroelectric power. The states from Colorado west have only 7.5 per cent of the population, but 39 per cent of the hydroelectric development.

These apparent anomalies are not difficult to explain. Falling water is a source of power, but we must have fall as well as water. In the Appalachian region there is ample water and moderate fall. In the Mississippi valley the fall is slight and difficult to utilize, except in rare instances. From the Rocky mountains to the Pacific we have plenty of fall, but are frequently short of water. In the immediate vicinity of the Sierra Nevadas there is an abundance of water and many falls which can be utilized at moderate cost.

The Pacific coast states, without coal, and until the development of the southern California oil fields, without fuel of any kind, were quick to grasp their opportunites. What was done in other parts of the country by means of fuel, they hastened to do with the "white coal". Thus, we see that the proportion of the total central station power, which is generated by water, is much greater in the far west than elsewhere. This appears from the following table:

PERCENTAGE OF TOTAL CENTRAL STATION POWER GENERATED BY WATER

New England	21.1
Middle Atlantic	22.2
East North Central	12.2
West North Central	14.3
South Atlantic	40.4
East South Central	10.6
West South Central	2.5
Mountain	64.8
Pacific	58.6

The three Pacific coast states, with 4.6 per cent of the population, have 12.3 per cent of all the central station power in the United States. Of this, nearly 60 per cent or 7.2 per cent of all central station power in the country is hydroelectric.

Digitized by Google

Now, what are the possibilities? In Water Supply Paper 234, United States Geological Survey, Mr. M. O. Leighton gives some estimates of the potential water power of the United States. Although his paper is entitled "Undeveloped Water Powers," his estimates appear to cover the total water power possibilities, without regard to what portions have already been developed. The paper was published in 1909, and the estimates probably correspond to the data at hand in 1908. The state of Pennsylvania is expressly excluded as information was not available to permit an estimate for that state. Two estimates were made—one, regarded as the absolute minimum, based on the stream discharge "for the lowest two consecutive seven-day periods in each year;" the other, described as "assumed maximum," being the quantity which could be generated during six months in the year. Neither estimate takes any account of storage.

The first is stated as 36,916,250 h.p., and the second as 66,518,500 h.p. Mr. Leighton estimates further that, by the use of all practicable storage sites, the grand total of possible water power development in the United States will be at least 200,000,000 h.p.

These estimates include a minimum of 5,800,000 h.p. and "assumed maximum" of 6,500,000 h.p. for the Niagara river. Under present treaty provisions, not more than 25 per cent of the possible power at Niagara falls can be developed, and of this the United States is entitled to only about 36 per cent.

In 1912 the Commissioner of Corporations revised Mr. Leighton's estimates by making the above correction for the Niagara river, adding 331,000 h.p. for Pennsylvania, and 117,750 h.p. for some other changes, and cutting one-sixth off the whole thing for good measure, arriving finally at the following figures:

	Minimum h.p.	Assumed maximum h.p.
North Atlantic	2,225,000	4,092,000
South Atlantic	2,344,000	4,256.000
North Central	1,733,000	3,558,000
South Central	1,438,000	2,785,000
Western	18,996,000	36,707,000
United States	26,736,000	51,398,000

The Commissioner refused to consider the possibility of greater development by storage. He says: "Any estimate including storage, therefore, must be mainly theoretical." Just what he means is not clear, but his purpose in omitting an important element in power development is obvious.

Digitized by Google

The above figures are not particularly reliable. They are largely speculative, and are based on very meagre data and grossly inadequate surveys. Moreover, the motive underlying the estimates of the Commissioner of Corporations was not honest. However, we may accept them, tentatively, and see to what conclusions they will lead us.

The following table gives the installed water powers side by side with the minimum potential power as estimated by the Commissioner of Corporations:

	Minimum potential power	Installed power
North Atlantic	2,225,000 h.p.	2,134,000 h.p.
South Atlantic	2,344,000 "	589,000 "
North Central	1,733,000 "	729,000 "
South Central	1,438,000 "	79,000 "
Western	18,996,000 "	1,229,000 "
United States	26,736,000 "	4,760,000 "

It appears from this table that the north Atlantic states have practically exhausted all their available water power, notwithstanding the Niagara developments aggregate only about 270,000 h.p. on the American side, instead of the 518,000 h.p. included in the Commissioner's estimate. The south Atlantic states still have a possible 2,000,000 h.p., and the central states about 2,000,000 h.p. more, but nearly all the water power possibilities of the future are west of the eastern boundary of Colorado, where there yet remains, even by the minimum estimate, and with no allowance for storage, nearly 18,000,000 h.p. undeveloped. On the basis of the "assumed maximum," the undeveloped possible water power in the western states exceeds 35,000,000 h.p. What this would be if storage possibilities were considered, I do not know.

The three Pacific coast states alone contain about 45 per cent of the potential water power of the country. Their aggregate present development is about 880,000 h.p., leaving possibilities from a minimum of 10,524,000 h.p. to an "assumed maximum" of 22,298,000 h.p. without considering storage.

The "assumed maximum" of potential water power, as estimated by the Commissioner of Corporations, is rather in excess of the present total installed primary power of the United States, including the equivalent of the steam locomotives now in service. This, however, is not to say that if all of this water power were

Digitized by Google

now installed, the steam plants would cease to operate. Seventy per cent of the possible water power is in the western one-third of the country, with 7 per cent of the people. No matter what the population may become numerically, it is probable that fully one-half will always, as now, live in the great Mississippi basin, for this is the region best adapted to the production of the staples of agriculture and animal husbandry. We are not justified in anticipating such improvement in the art of transmission as will permit the use along the Missouri river of power generated in the Mountain and Pacific states. I do not know the longest transmission line now in operation—someone is always going his predecessors one better—but probably the 238-mile (383.02-km.) line of the Southern Sierras Company is the limit of present practise. Let us suppose that power might be transmitted 500 miles (804.6 km.) with a reasonable loss. A belt 500 miles wide with the summit of the Sierra Nevadas as its western limit would have as its eastern boundary a line passing near Great Falls, Montana, Pocatello, Idaho, across the western edge of Great Salt Lake, crossing about the middle of the southern boundary of Utah, and near Gallup and Silver City, New Mexico. Clearly, no conceivable development in that belt of country would ever call for the use of 10,000,000 to 22,000,000 h.p. How would you like to be the grinding monopoly to own all these power sites and pay taxes on them until such time as you might develop them with a reasonable chance to earn more than their fixed charges and cost of operation? This is the "bogie man" with which our conservation friends are trying to frighten us.

What is to become of all this power if it shall ever be developed? The present fixed installed primary power of the United States, including steam locomotives, is between four-tenths and five-tenths of a horse power per capita. On this basis the minimum potential water power in the Pacific coast states alone would provide for a population of twenty to twenty-five million people west of Great Salt Lake. What would they do? They would be much in the position of the Irish woman and the Chinaman who were ship-wrecked on a desert island—they made money doing each other's washing.

Every important hydroelectric enterprise from the first Niagara installation to the Keokuk plant, has been financed on the basis of an existing market for at least a part of the output. No responsible banking house will listen to a power scheme which can not show a market in sight sufficient to pay fixed charges. The Niagara Falls Power Company was financed on the power con-

Digitized by Google

sumption in Buffalo and other nearby cities. The Standard Electric and the Bay Counties Power Company, as well as other properties now belonging to the Pacific Gas and Electric Corporation, had their markets in sight around San Francisco bay. Snoqualmie Falls had Seattle, Tacoma and the entire Puget Sound district. The McCall Ferry plant is only seventy miles (120.7 km.) from Philadelphia, and the Mississippi River Power Company had a 60,000 h.p. contract with St. Louis before work was begun at Keokuk.

So it has been with all of them, but it can not continue to be if anything like the enormous quantities of power above mentioned are to be developed within limited areas. We must go back to something like the methods of early New England days. We must choose those industries in which power is the all-important element, locate them within transmission distance of the power sites, and then finance the industries by virtue of their own strength, regarding the power merely as an adjunct. This is in strong contrast with the method of building a power plant and then waiting for someone else to build the factories and buy the power.

Up to this time our power development has always followed a demand instead of seeking to create it. This has not been so generally true elsewhere, nor have we followed the same method in other activities. The Union Pacific railroad would be nonexistent today if its promoters had waited for the Indians to petition Washington for improved transportation facilities. The coal range would still be in universal use if the gas range had not been put on the market until the housewives clamored for it.

In the United States most of our power has been used to meet the every-day demands for light, heat, transportation and the operation of such industries as are incidental to city life. Outside of Niagara Falls, we have not developed any electro-chemical or electro-metallurgical industries worthy the name. Abroad it has been quite different. The Norwegian Nitrogen Company, for example, located its plants near the power sites, developed power, not as an end in itself, but as an adjunct only, and built up an enormous industry where before there had been nothing. In 1913 it had in operation 260,000 h.p. used solely for the fixation of atmospheric nitrogen, and had planned the development of 280,000 additional h.p. The furnace and process by which this is done were not invented until 1903.

In 1910 there were in the French Alps operating water power plants aggregating 475,000 h.p., 80,000 h.p. more under construc-

Digitized by Google

tion, and 700,000 h.p. projected. Of the power produced at that time, 210,000 h.p. was consumed in electro-metallurgical work and 60,000 h.p. in electro-chemical industries. These made up 57 per cent of the total. Of the remainder, 30,000 h.p. was used in the paper and wood industries, and 165,000 h.p. for commercial power, light and traction. The distribution of this power among the industries is significant.

It has often been said that fixation of atmospheric nitrogen is not practicable in the United States because of the high cost of power. Let us look into this briefly. Nitrate of soda costs $70.00 per ton (1 long ton = 1.01 metric ton) in New York. This is equivalent to $95.00 per ton for pure nitric acid. The operations in Norway and elsewhere produce about 500 kg. (1,102.3 lb.) of nitric acid per kw-yr., or 1.82 kw-yr. per ton of acid.

The Mississippi River Power Company supplies power to St. Louis at $24.00 per kw-yr. at 60 per cent load factor. At this rate the power necessary to produce one ton of nitric acid would cost about $44.00. The margin between this and a selling price of $95.00 is sufficient to warrant a very careful inquiry before accepting the statement that "it can not be done."

The greater part of the hydroelectric power in the French Alps devoted to electro-metallurgical work, is used for the manufacture of special alloys, such as ferro-tungsten, ferro-molybdenum, ferro-titanium, etc. The Paul Girod works alone produce more than two million dollars worth of these alloys annually. The western part of the United States is as well supplied with the raw materials for such manufacture as any part of the world.

In northern California the production of pig iron in the electric furnace was inaugurated about six years ago. This experiment has been attended with considerable technical successs though with what commercial results I am not advised. Doubtless that and similar enterprises elsewhere will ultimately succeed. When they shall do so, their demand for power will be very large.

Such and many other industrial undertakings will grow up in the western part of the United States when a Federal policy of encouraging business enterprise and initiative shall take the place of the present obstructive tactics whose justification is attempted on the ground that someone may corner 22,000,000 h.p. in water falls, and that the world would then freeze to death in about five thousand years. When that freezing takes place, certain Federal bureaus and officials will not be suffering from the cold.

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers New York, February 14, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

INTERNAL TEMPERATURES OF A. C. GENERATORS

BY RALPH KELLY

ABSTRACT OF PAPER

The paper deals with the internal temperatures of a number of typical large a-c. generators; this temperature being measured by a thermo-couple placed between armature coils in the same slot and in the center of the core. The difference between these measured internal temperatures and the corresponding surface temperatures in the tests given varies from 0 deg. to 35.5 deg. This wide divergence is explained by the aid of the tests and of calculations. A method of calculation for internal temperatures is given which is based on simple heat laws and on data obtained from many tests. By means of the tests and of parallel calculations, the effect on the internal temperature of changes in frequency, core length, thickness and quality of insulation, armature current density and core densities, is explained. The capacity of the end windings to dissipate heat from the center of the core is also discussed. In conclusion, it is stated that although the wide divergence between surface and internal temperatures of different classes of generators is regular and can be justified, yet it is plain that there is no one average figure that can be used for that difference for all classes of a-c. generators.

THERE have been many attempts, more or less unsuccessful, to establish average figures representing the difference between internal and surface temperatures of different classes of a-c. generator stators. When test results from a large number of generators are reviewed, the engineer's first conclusion is apt to be that there is no relation or consistency between temperatures measured by thermometer and by thermo-couple. One generator may have a difference between inside and outside temperatures of only a few degrees while in others a difference of fifty degrees and more may be found.

If, however, these test results are checked by calculations based on fairly simple laws of heat flow, it will be found that these widely varying results can be satisfactorily explained and shown to be consistent. Such a comparison will also explain why attempts to establish average figures are fore-doomed to failure. Frequency, voltage, quality of insulation, copper and core densities, shape of slots, and core length, all have a bearing on

Manuscript of this paper was received November 10, 1916.

Digitized by Google

the drop in temperature from the inside to the outside of the stator. With so many factors affecting the temperature drops there is no average figure that can be used for the difference between internal and surface temperatures for all classes of a-c. generators.

In the following pages such a comparison of typical test results and the corresponding calculated temperatures is given. The test figures have been selected for this purpose from some fifty odd tests that have been made under full-load current and voltage conditions on generators ranging in size from 1000 kv-a. to 20,000 kv-a. and in speed from 100 rev. per min. (in vertical waterwheel generators) to 1500, 1800 and 3600 rev. per min. (in turbo generators). In one series of tests measured temperatures are available under different load conditions and at all important parts of the slot and core. In the other only the maximum internal slot temperature and the surface temperature readings are available. In such cases, however, if the calculated and tested temperatures agree reasonably, the calculated temperature at the intermediate points in the heat path may be considered reliable. We may confidently use these test temperatures and these calculated temperatures, checked by test, to show the magnitude of the effects of the different factors on the internal temperatures.

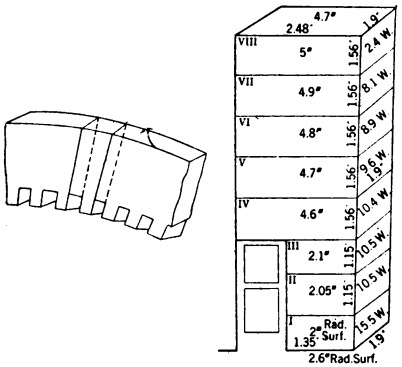


FIG. 1—SEGMENT OF CENTRAL PACKAGE WITH UNIT PACKAGE SELECTED SHOWN IN DETAIL AT RIGHT

In obtaining the calculated results, a part of the armature laminations included between two adjacent air ducts, and one tooth pitch in length, is selected for analysis. This portion of the armature with the parts of the armature coils embedded in it will be termed in the paper "a unit package," Fig. 1. As the losses in all unit packages are practically identical, the one in the center of the core is chosen for analysis because the internal temperature rise is usually the highest in that unit package. The losses are calculated under load conditions in the armature conductors and in the different sections of the armature laminations included in this unit package. The method of temperature

Digitized by Google

TABLE I

	Test 1		Test 2		Test 3		Test 4		Test 5		Test 6	
Kv-a	7,660		3,830		4,570		7,500		2,750		20,000	
Amperes	1,100		550		550		578		255 (2φ)		1,750	
Volts	4,000		4,000		4,800		7,500		5,400		6,600	
Per cent inductive P. F.	0		0		0		0		0		0	
Load tooth density in C. G.S lines sq. in.	114,000		105,500		126,300		118,100		120,500		114,500	
Load core density in C. G. S. lines sq. in.	66,000		60,600		73,200		69,000		97,800		67,700	
Arma. copper density, amps. per sq. in.	2,180		1,090		1,090		1,605		2,730		1,845	
Cycles	50		50		50		25		62.5		50	
Rev. per min.	400		400		400		375		375		375	
Core length in inches	23½		23½		23½		45		16½		41½	
Velocity in air gap cu. ft. per min.	8,250		8,250		8,250		6,460		5,700		8,600	
Velocity in air duct cu. ft. per min	3,300		3,300		3,300		2,580		3,800		3,440	
Velocity in core cu. ft. per min.	2,000		2,000		2,000		1,290		2,140		2,230	
Vel. rear of core cu. ft. per min.	1,500		1,500		1,500		950		1,600		1,670	
	Tested values	Calc. values	Tested values	Calc. values	Tested values	Calc. values	Tested values	Calc. values	Tested values	Calc. values	Tested values	Calc. values
Calculated hot spot temp.		**72.5**		**36.5**		**53**		**35**		**89**		**89**
Test thermo-couple temp.	**73.3**		**39.4**		**59**		**36**		**82**		**93**	
Calculated rear of core temp.		**45**		**28.5**		**49**		**22.3**		**65**		**48**
Test rear of core temp. by thermometer	**40**		**30.5**		**47.5**		**23**		**56**		**43.5**	
Max. Temp. Sec. I	61.7	61.3	44.7	46.3	66.7	68.5		33.1		77.2		70.8
" " " II		61.4		46.3		69		32.5		77.7		70.3
" " " III		58.2		45		66.5		30.8		76.7		67.3
" " " IV	54.5	54	43.6	41.8	62.5	62.1		27.7		74.4		62.2
" " " V		51.1		39.5		58.3		25.7		71.1		58.5
" " " VI	54.5	48.7	44.4	37.5	62	54.8		24.4		66.8		55.7
" " " VII		46.9		35.8		51.8		23.6				53.5
" " " VIII	47.9	45.7	38.1	34	55.5	50		23.1				52
" " " IX								22.9				
Thermometer rise arma. copper	**44**		**17**		**26.5**		**36**		**47.5**		**57.5**	

All temperatures listed are temperature rises above inlet air.

Digitized by Google

calculation used is essentially a cut and try method. A probable armature copper temperature in the central unit package is first assumed; the flow of heat to the air ducts, armature tooth, and to the coil ends is then calculated. If the assumed copper temperature is correct, the heat flow from the copper to the tooth determines the temperature drop across the insulation and the temperature of the armature tooth. The laminations of the unit package are divided into sections to facilitate the calculation of the heat flow through the core. With the tooth temperature as a basis the heat flow from section I to the air ducts, to the air gap, and to section II is determined. This procedure is followed from section to section until the rear of the core is reached when if the proper initial temperature has been assumed the total loss will have been dissipated to the cooling air. If the loss dissipated is greater or smaller than the actual loss in the unit package, a new trial temperature must be assumed and the calculation repeated.

Table I gives the calculated and test temperatures with other data for four generators that are similar in design except for frequency and core length. In test 1, 2 and 3 the temperature measurements were made by thermo-couple at several points of the unit package for three conditions of load. In tests 4, 5, and 6 only the internal copper temperature and the surface temperatures were measured. The close agreement of the calculated and tested temperatures in these last three tests justifies the use of the calculated temperatures for the intermediate parts of the unit package in discussing the effect of different factors on the internal temperatures. While the tested internal copper temperatures vary from 36 deg. to 93 deg. the average difference between the tested temperatures and the corresponding calculated temperatures is less than 3 deg.

Method of Calculation

The object of the calculation is to determine the maximum measurable temperature to which the armature insulation is subjected, which in practise is usually the temperature measured by thermocouple placed between coils in the same slot and in the center of the core. This temperature is calculated by the use of simple heat laws and of empirical data based on a large number of experimental tests. The capacity of air-cooled surfaces to dissipate heat, the correct velocity of air passing over the air-exposed surfaces of a generator, the temperature rise

Digitized by Google

of that cooling air, and the heat conductivity of the heat conducting paths of a generator, must be determined in order to calculate this temperature. The calculation applies only to radially ventilated salient pole generators with enclosing end bells. For other types of generators suitable changes, based on appropriate test data, must be made in the calculation.

The temperature rise of an air-cooled surface varies with the air velocity and may be determined when the relation between the air velocity and the heat dissipated per unit surface per degree rise are known. It is assumed that the heat dissipated from a surface at any given velocity increases directly with the temperature rise, which permits the use of the equation

$$W = \frac{T}{K} \qquad (1)$$

W = watts radiated per sq. in. of surface.
T = temperature rise of surface above cooling air.
K = a constant depending on the air velocity.

The data for the constant K (Fig. 3) has been determined from tests where air at different velocities has been passed over heated surfaces.

In Table I the air velocities through the armature core are tabulated with the corresponding values of K. In long core machines with enclosing end bells insuring practically uniform velocities in the air ducts, the following values generally apply:

(a) The velocity of air in the air gap is 75 per cent of the peripheral speed of the rotor.

(b) The velocity of air in the air duct at the tooth is 30 per cent of the peripheral speed.

(c) The velocity of air at the back of the core is 75 per cent of the air-duct core velocity.

These values are by no means constant but should be varied with different methods of ventilation as well as different proportions of the armature core. They are based on measurements taken on a number of generators and checked, in common with the other constants involved, by the agreement between calculated and test temperatures.

The losses generated in all unit packages are practically identical. For convenience in calculation this unit package is divided into sections as shown in Fig. 1; the dimensions shown in Fig. 1 are taken from the generator in Test 1. The iron and copper losses under load conditions are calculated for each sec-

Digitized by Google

tion. An allowance is included for increased saturation due to the influence of the armature reactance, for eddy current losses in the conductors, and when operating at high power factors, for distortional losses. Recognizing that the density in the core is not uniform, the distribution of the loss across the core depth is assumed to vary in such a manner that the loss in the section next to the bottom of the slot is greater than the loss at the rear of the core by the ratio $\frac{\text{pole pitch} + \text{core depth}}{\text{pole pitch}}$. In long core machines there is a negligible flow of heat from the central unit package to the coil ends, so that the watts generated in that unit package must be dissipated through the medium of its own surfaces exposed to the cooling air. In short core machines the heat flowing to the coil ends from the central package should be calculated and deducted.

The cooling air in passing through the machine has its temperature raised by the losses that are dissipated to it. The amount by which the temperature of the cooling air is raised before it reaches the first section of the unit package may be calculated from the fact that 1 kw. of energy dissipated to 100 cu. ft. (2.8 cu. m.) of air at an initial temperature of 25 deg. cent. will raise the temperature of that air 18 deg. cent. in one minute. The temperature rise of cooling air from section to section may be calculated similarly. Due to the rise of cooling air through the air duct, a correction is made for the flow of heat toward the slot from the back of the core by taking a proportionate number of watts from the rear section and arbitrarily adding them to the losses in the first section.

In figuring the heat flow through the package, the following constants are used for heat conductivity through the different materials.

Lengthwise in iron laminations 1.1 watts per cu. in. per deg. cent.

Crosswise in iron laminations 0.045 watts per cu. in. per deg. cent.

Insulation,* 0.0025 to 0.005 watts per cu. in. per deg. cent.

Copper, 8 watts per cu. in. per deg. cent.

The heat conductivity of the insulation not only depends on the materials used but depends greatly on the compactness of

*"Heat Path in Electrical Machinery", Harold D. Symonds and Miles Walker, *Journal I. E. E.*, Vol. XLVIII., 1912.

Digitized by Google

the coil. In a loosely wound coil with minute air spaces, a low value of conductivity must be used.

As the first step in the calculation of heat flow, the temperature rise of the copper above the inlet air is assumed. The heat generated in the armature conductors included in the central package must be transferred to the air duct, to the coil ends, or to the armature iron. The temperature drop through the insulation for a given watt flow per 1 in. (25.4 mm.) length of coil is expressed by

$$T = \frac{\text{single wall thickness of insulation} \times \text{watts conducted.}}{\text{mean periphery of coil insulation} \times \text{conductivity of insulation.}} \qquad (2)$$

Using equations (**1**) and (**2**) the loss transferred from the copper

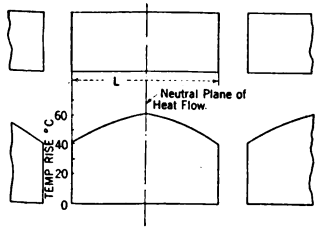


FIG. 2—TEMPERATURE RISE ACROSS LAMINATIONS

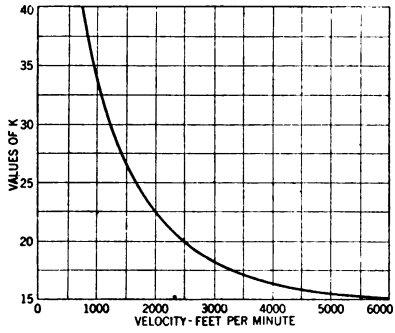


FIG. 3—HEAT DISSIPATION FROM AIR COOLED SURFACES

to the air at the air duct may be determined by trial. The temperature difference between the copper and the iron to permit the transfer to the iron of the remaining loss is calculated from (**2**). This energy is divided equally among the three sections of the tooth.

In determining the temperature difference between the copper and tooth it must be considered that the temperature of the iron of a unit package varies along its length. In any unit package the heat that is radiated to the air duct must be conducted across the laminations. To permit this flow there must be a temperature difference between the laminations at the center of the unit package and at the air duct. The center of the unit package (Fig. 2) is the neutral plane of heat flow and consequently the hottest part of that package. The heat flow from the copper

Digitized by Google

to the iron is then variable. This flow varies along the length of the unit package, being small, if any at the center and increasing from point to point to the air duct. The temperature rise of the laminations in the unit package is assumed to be a straight line. From this assumption it develops that the temperature difference previously calculated between the copper and iron is the temperature difference between the copper and the laminations midway between the neutral plane and the air duct. The heat dissipated to the air duct from section I is calculated by trial from (**1**) and from

$$T = \frac{W}{0.045} \times \frac{L}{8}$$

T = temperature difference between the plane of average temperature and the air duct iron.
W = watts flow per sq. inch from section I to air duct.
L = unit package length.

This last calculation also determines the temperature of the neutral plane. In figuring the air-duct dissipating surface, one-half the surface of the air-duct spacers is considered as effective radiating surface in addition to the surface of the laminations at the air duct. From the temperature of the neutral plane and equation (**1**) the heat flow from section I to the air gap can be calculated.

The difference between the total watts in section I and the watts dissipated to the air ducts and gap must flow to section II. It often occurs that more than the total watts are dissipated from section I to the cooling air in which case there is a flow from section II to make up the deficiency. This heat flow from section I to II or vice versa causes a temperature difference from which the maximum temperature of section II is determined. The total watts in section II consist of the watts from section I the watts from the armature copper, and its own loss. The same procedure is followed as in section I, except that all of the loss dissipated to the cooling air must be by means of the air ducts alone.

This procedure is followed from section to section until the calculation for the last section is completed when, if the correct copper temperature has been assumed, all of the loss will have been dissipated. If there is any energy loss remaining that has not been dissipated, a higher copper temperature should be assumed; if there is not enough loss to satisfy the condition, a

Digitized by Google

lower temperature should be assumed and the calculation repeated.*

The effect of various generator proportions and characteristics upon internal and surface temperatures and on their relative values, based upon actual test data and data obtained by the use of this method of calculation, will be discussed in detail in the following paragraphs.

Effect of Frequency

In Table 1, the 50-cycle generator, test 6, has practically the same core length and armature densities as the 25-cycle generator, test 4, yet its internal copper temperature rise measured by thermo-couple is 57 deg. cent. higher than that of the 25-cycle generator.

The maximum temperature rise of the copper above the inlet air is the maximum temperature rise of the armature tooth in the center of the core plus the temperature drop through the armature insulation at that place. The maximum temperature rise of the armature tooth depends to a small extent on the heat flowing to the tooth from the copper and largely on the iron loss in the teeth and core.

The difference in the internal temperature rises experienced in generators of different frequencies is caused mainly by the difference in the core loss. In the 50-cycle generator the losses are considerably greater than in the 25-cycle generator, even though the core densities in the 50-cycle generator are slightly smaller. The temperature difference in the two machines due to the increased iron loss caused by the higher frequency is accounted for very nearly by the temperature rises in section I of the tooth. These rises are 70.8 deg. cent. for the 50-cycle generator and 33.1 deg. cent. for the 25-cycle generator, as compared with the corresponding measured copper temperatures of 93 deg. cent. and 36 deg. cent. It is noted that the difference between the armature-tooth temperature rises for the two generators is somewhat smaller than the difference of the thermo-couple temperature rises; this being due to a greater temperature drop through the armature insulation in the 50-cycle generator caused by a greater flow of heat from the copper to the iron.

The 50-cycle generator, test 1, may also be compared with

*This form of temperature analysis was devised by Mr. B. G. Lamme a number of years ago, and was more completely worked out and applied by his assistant, Mr. F. T. Hague, in 1913.

Digitized by Google

the 25-cycle generator, test 4, to show the effect of frequency on internal temperature rises. The comparison is not as direct as in the previous case, for, although as before the armature densities are practically the same in both cases, the core length of the 50-cycle generator is roughly one-half that of the 25-cycle generator. Yet, in spite of this advantage, the 50-cycle generator armature-tooth temperature rise is much higher than the same temperature rise of the 25-cycle generator, although the difference is not as great as in the previous case. The reasons for the difference in temperature of the two 50-cycle generators will be discussed later.

If the 50-cycle generator, test 6, were operated at 60 cycles with the same armature densities, the additional losses caused by the higher frequency would increase the temperature rise measured by thermo-couple to a still greater value than 93 deg. cent. Thus, in comparing the two generators, tests 4 and 6, on the basis of the extreme commercial frequencies of 25 and 60 cycles, the differences in internal temperature would be even greater than on 25 and 50-cycle basis.

From the test results in column 4 it is evident that in large 25-cycle water-wheel generators the internal temperature will be approximately the same as the copper thermometer temperature and will always be relatively low. This is confirmed by several tests on 25-cycle generators; for examp e:

Rating	Phase	Rev. per min.	Volts	Surface temperature rise	Internal temperature rise
12000 kv-a.....	3	116	11000	47	47
12000 kv-a.....	3	94	11000	27.5	33
4500 kv-a.....	1	500	11000	45.5	55.5
7640 h.p.....	3	375	13000	31.5	35.5
6250 kv-a.....	3	1500	6600	22	31.

For 50 or 60-cycle maximum rated generators there is always a large difference between thermometer and thermo-couple readings. The thermometer readings in many cases are not appreciably greater than for 25 cycles but the thermo-couple readings show a large difference over those for the lower frequency.

Effect of Core Length

A change in core length affects the internal temperature in two ways; it changes the volume of armature material to be ventilated and to a lesser extent it changes the proportion of

Digitized by Google

heat transmitted to the coil ends. Of the two effects the change of armature material to be ventilated with a change of core length is the most important. With a given pole arrangement the inlet area, between the poles, for the armature ventilating air is fixed. An increase in core length, with other conditions remaining the same, results in a proportional increase in the armature losses. The volume of cooling air through the fixed inlet area remains practically constant with a given fan pressure so that there is less cooling air per kw. loss than before and consequently the temperature rise increases. In the case where a given generator is increased in core length and it is required that the temperature rise be kept constant, it is often possible to change the ventilating fans to increase the air pressure, which results in an increase in air volume. This increase is usually not commensurate with the increase in armature loss, so that this loss must be reduced by using more material. This makes it evident that there is a definite core length in radially ventilated generators for each number of poles and each rotor diameter that it is inefficient to exceed.

The end coils which are directly exposed to the cooling air have the capacity to dissipate heat; this capacity varying with the temperature difference between copper and air, the air velocity, and with the quality and thickness of the insulation. With the heat dissipating capacity of the coil ends constant, it follows that with an increase in core length the heat flow decreases from the center of the embedded armature coil to the coil ends. For long-core generators, *i.e.*, generators with a core length greater than 30 in. (76.2 cm.), it has been found by checking a number of tests, that with a normal winding practically no heat flows from the center of the coil to the coil ends. On the other hand in short-core generators an appreciable part of the "buried" copper loss will be dissipated from the coil ends.

The two 50-cycle generators, tests 1 and 6, afford an excellent example of the increase in temperature rise with an increase in core length, other conditions remaining practically the same. The temperature increase of the long-core generator, test 6, of 19.7 deg. cent. more than the generator, test 1, is caused principally by the poorer ventilation of the long-core generator due to its greater core length. The coil ends but slightly affect the temperature difference in this case, for in one generator only 10 per cent of the "buried" copper loss of the central unit package is dissipated to the coil ends while in the long-core generator

Digitized by Google

practically none of that loss is conducted from its central unit package to the coil ends.

*Effect of Thickness, Compactness and Quality of Insulation

In long-core a-c. generators the flow of heat from the armature copper to the cooling air is through the insulation to the laminations, so the temperature drop through that insulation is an important factor in determining the internal copper temperature. This temperature drop varies inversely as the heat conductivity, which in turn depends on the compactness and quality of insulation. The numerical value of the heat-conductivity of armature insulation varies over a broad range, being different even in samples made up of the same insulating materials; this difference being due to the effect of air pockets in the insulation. Tests made by H. D. Symonds and Miles Walker, previously referred to, illustrate the great effect of air pockets on the value of heat conductivity of insulation. In these tests the heat conductivity of insulation composed of empire cloth and mica wound tightly was almost double that of the same material wound loosely. These tests, checked by the calculations of generators, indicate that the heat conductivity of armature insulation varies within the approximate limits of 0.0025 to 0.005 watts per cu. in. per deg. cent. The lower value is for hand wrapped unimpregnated insulation and the higher value for compact machine wrapped insulation.

The temperature drop through armature insulation also varies with the thickness of the insulation. This means that the higher the voltage of a generator for a given heat flow the greater will be the temperature drop across the insulation providing the same type of insulation is used.

In the generators under discussion the armature insulation for the one in tests 1-2-3 consists of mica and fibrous material; the entire coil being hand wrapped and thoroughly impregnated to eliminate as completely as possible minute air spaces. The conductivity constant used for this material is 0.004 watts per cu. in. per deg. cent. which, in test 1, results in an average temperature drop in the central unit of 22 deg. between the copper and iron.

For the generator in test 5, the armature coil is made up of

*"Rational temperature guarantees for large a-c. generators", F. D. Newbury Proc., A. I. E. E., Nov. 1916

Digitized by Google

stranded conductors insulated from each other with asbestos and mica, the whole then insulated with a wrapper of thin paper covered with splittings of mica. This wrapper is applied while heated and under tension, so that when completed the coil is a relatively solid mass with a high percentage of mica. Due to the use of superior insulation, the insulation thickness is the same as in the previous case, even though the voltage is somewhat greater. In this case with approximately the same heat flow per square inch as for the generator, test 1, the temperature drop through the insulation is only 16 deg.

If these generators had been wound for 13,200 volts, the insulation thickness would be approximately doubled. The temperature drop through the insulation would increase approximately in the same proportion to the increase in insulation thickness, which in turn would increase the internal temperatures.

Effect of Current Density

The current density has an important and direct bearing on the internal temperature since it largely determines the heat loss that must be transmitted through the insulation. The total copper loss is the I^2R loss plus the eddy current loss. Neglecting the eddy current loss the drop through the insulation in any given generator is very nearly proportional to the square of the armature current or to the square of the current density. A low current density reduces the drop not only by reducing the loss but also by increasing the area of the heat path, since a larger slot is required for the increased copper section. With a given limiting temperature drop through the insulation, the use of machine wrapped mica insulation, with its better heat conductivity, justifies the use of higher armature copper densities.

The test temperatures in tests 1 and 2 clearly illustrate the effect of the armature current density on the temperature drop through the insulation in the same generator. In test 1 with a current density of 2180 amperes per sq. in., the armature copper temperature rise is 11.6 deg. cent. higher than the maximum temperature of section I. In test 2 with a current density of 1090 amperes per sq. in. the armature copper temperature rise is 5.3 deg. cent. lower than the maximum temperature of section I.

Effect of Tooth and Core Densities

The tooth and core densities have a similar effect on the internal temperature as the generator frequency, since both affect the copper temperature through the core loss.

Digitized by Google

Tests 2 and 3 bring out very clearly the effect of increasing the saturation of the armature iron, other conditions remaining the same. The test conditions for test 4 were exactly the same as for test 3 with the exception that the armature voltage was increased 20 per cent which proportionately increased the tooth and core densities. The result of this increase was to raise the internal copper temperatures from 39.4 deg. to 59 deg. cent. even though the copper loss remained the same. This difference in copper temperatures is very nearly the same as the difference in the maximum temperatures of the armature iron; indicated in the table by the test temperature of section I. The difference in copper temperatures in the two tests is slightly less than the difference in the iron temperatures, this being due to a slightly increased heat flow in test 4 from the iron to the copper. Both tests and calculations show that a variation of the iron density alone produces a change in the internal temperature of the copper almost proportional to the change in iron loss.

Effect of the End Windings on the Internal Temperatures

It has been previously pointed out that the end coils usually have the capacity to dissipate heat from the embedded part of the armature coil. The test temperatures in tests 1, 2 and 3 show roughly the effect of this flow under different conditions of load for the same generator. In test 1, with a comparatively large copper loss, the temperature of the armature copper is 11.8 deg. cent. higher than the maximum temperature of section I indicating a comparatively large flow of the buried copper loss from the copper to the iron. In test 2, with roughly one-quarter of the copper loss in test 1 and a slightly lower iron loss, the armature copper temperature is 5.3 deg. cent. lower than the *maximum* temperature of section I, indicating practically no heat flow between the copper and the iron. In test 3, with the same copper loss as in test 2, but a greater core loss, the armature temperature is 7.7 deg. cent. lower than the maximum temperature of section I, indicating that there is a small heat flow from the iron to the end coils in addition to that of the buried copper loss.

The calculation of the heat flows from the central unit package to the end windings n these three tests not only confirms the test results, but gives more exactly the actual conditions of that heat flow. In test 1, 10 per cent of the buried copper loss of the central unit package was conducted to the end coils. In test 2

Digitized by Google

all of that loss was conducted to the end coils besides which 0.4 watts iron loss was conducted from the central unit package through the insulation to the end coils. In test 3, all of the buried copper loss was again conducted to the end coils, and the iron loss conducted from the central unit package was increased to 1.4 watt. This is equivalent to approximately 25 per cent of the buried copper loss in the central unit package.

The increase of end winding temperature of 19.6 deg. cent. in test 3 over test 2 shows that in fairly long-core machines it requires the cumulative effect of but a very small watt flow from each unit package to raise the temperature of the end windings a large amount. With long-core high-current-density machines with a large temperature difference between the center of the machine and the cooling air at the end coils, a very small percentage watt flow per inch length of coil will satisfy that difference and this flow may be neglected when analyzing the heat flow of the central unit package.

Relation of Internal Temperatures to Surface Temperatures

It has been shown previously in this paper that the maximum tooth temperature of a generator is very closely related to the internal copper temperature. An inspection of the detailed test temperatures in test 1, 2 and 3 will show that the core surface temperature measured by thermometer varies almost in proportion to the tooth temperature.

A thermometer placed on the armature end coils rises after shut down when the flow of the ventilating air is stopped so that the recorded test temperature rise of the end coils will be between the surface temperature of the coils during running conditions and the internal copper temperature of the end coils. This test temperature in any machine wil be nearest the operating surface temperature or the internal temperature of the end coil copper, dependent on the rate of cooling of the generator after shut down, on the methods of placing the thermometers on the coils and on the degree of sluggishness of a thermometer in recording temperature changes.

The variations incurred in measuring the end coil temperatures make the relation between the internal copper temperature and the end coil temperature less direct than in the case of the iron temperatures. Nevertheless, an inspection of tests 1, 2 and 3 shows that a change in the internal copper temperature results

Digitized by Google

in a corresponding change in the end coil temperature as measured by thermometer.

Conclusion

The results of the tests in Table 1 show that there is a wide divergence between internal and surface temperatures in a-c. generator stators. In the preceding pages it has also been shown that the amount of divergence of the surface temperature from the maximum internal temperature depends mainly on frequency, core length, and armature voltage. Of the generators listed the greatest difference between surface and internal temperature is found in the 50-cycle generator, test 6; this temperature difference being 35.5 deg. cent. For a generator of the same characteristics except designed for 60 cycles and 13,200 volts, it is safe to say that the temperature difference between the surface and internal temperatures would be approximately 50 deg. cent. In the 25-cycle generator, test 4, which is similar to the 50-cycle generator, test 6, with the exception of the frequency, the internal and surface temperatures are the same. The results of these two tests show clearly there is no one value that applies to the temperature difference between surface and interna temperatures for all classes of a-c. generators. Furthermore, it is evident from these tests that surface temperatures measured by thermometer give no indication of the maximum temperature to which the insulation is subjected, unless all the factors that effect that temperature are given due consideration.

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 14, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

REACTORS IN HYDROELECTRIC STATIONS

BY J. ALLEN JOHNSON

ABSTRACT OF PAPER

The advantages and limitations in the use of current limiting reactors in hydroelectric stations are not so well recognized or understood as they are in steam turbine stations, but it is now coming to be realized that their use may be quite as justifiable and necessary in the former as in the latter.

The two beneficial results of reactance, protection and localization, are distinct; the former being associated with the square, and the latter with the first power of the reactance.

Of two detrimental results of reactance, or limitations to its use, one, that of voltage drop, is well understood but the other, the reduction of synchronous stability is not so well understood.

The installation of reactance usually results in a decrease in the stability of synchronism. Such stability may be expressed in terms of the angular phase displacement between two groups, due to a sudden load disturbance. Practically, complete instability or asynchronism occurs in a large station when the phase angle exceeds 90 deg. The asynchronizing effect of a sudden load change is approximately twice that of a gradual change of the same magnitude.

The origination of a power surge by sudden loss of load and the accompanying hunting oscillation is described. Increased reactance increases the amplitude of both the power surge and the phase-angle oscillation and also increases the period. A certain amount of reactance will result in complete asynchronism immediately following the load disturbance, and a smaller amount may cause troublesome and persistent hunting by forced harmonic oscillation of the turbine governors in combination with certain hydraulic conditions, such as long penstocks.

It is shown that these phenomena form a practical limitation to the use of reactance, in that the reactances necessary to create the conditions described are of the same magnitude as those often indicated for protective and localizing purposes. The actual occurrence of a surge is described.

THE THEORY and practise regarding the use of current-limiting reactance in steam turbine stations are now fairly well established and the advantages and limitations of reactors are well understood. Their use in hydroelectric stations, however, is not so general, nor are the limitations imposed by such service nearly so well understood as are those of the steam station.

The reasons for this apparent slowness on the part of the large hydroelectric stations to realize the benefits of reactance

Manuscript of this paper was received September 28, 1916.

Digitized by Google

are that the number of such stations is comparatively few, they do not in general lend themselves so readily to reactor protection, their growth to mammoth proportions has been somewhat slower, and so long as the principal function of reactance was believed to be the protection of the generating equipment, the necessity for it in the hydroelectric station was not apparent.

Recently, however, it has been realized that the chief function

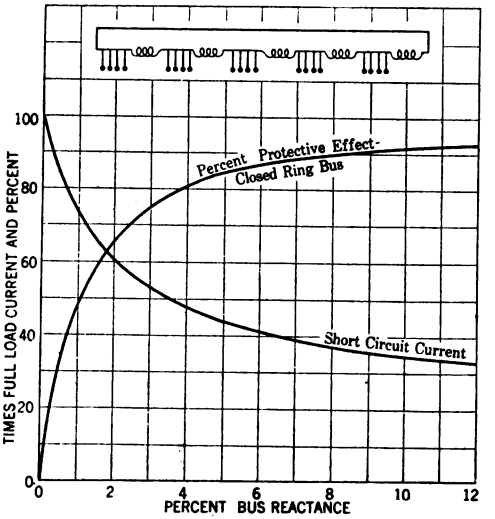


FIG. 1—PROTECTIVE EFFECT OF BUS REACTANCE

Generator reactance—20%
20 generators in groups of 4
Bus reactance 4%
Bus reactance based on rating of one generator
Fault at any point on bus

Per cent protective effect—$100\left(1-\frac{x_0^2}{(x_0+x_2)^2}\right)$

x_0 — resultant reactance of generators alone
x_2 — resultant reactance external to generators

of reactance is not the protection of the generators but the so-called "protection of service" or what the writer prefers to call the isolating or localization of disturbances. With this new viewpoint it has rapidly become apparent that reactance is just as necessary to the hydroelectric stations and just as valuable to them as to the steam turbine stations.

The load of a large hydroelectric station usually divides into three groups:

Digitized by Google

First, the existing local industries which adopt electric power when it becomes available.

Second, industries which build up about the power station, due to the availability of power at a low price.

Third, long distance load supplied to cities within transmission distance.

The requirements of each of these three groups, as well as the likelihood of their causing interruptions differ materially, making it desirable for their mutual benefit that they be operated from separate bus sections, with the consequent sacrifice of simplicity,

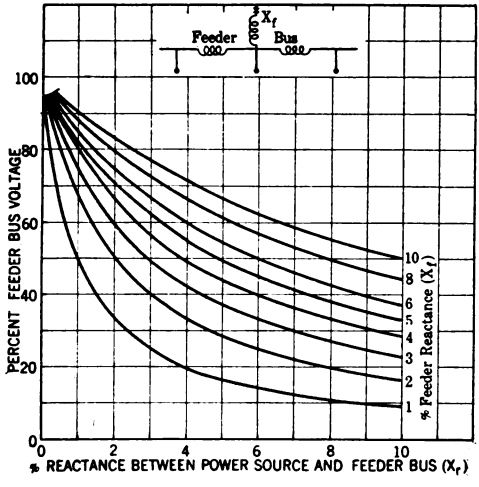


FIG. 2—ISOLATION EFFECT OF FEEDER REACTANCE

All reactance based on same kv-a. rating

$$\text{Per cent feeder bus voltage} = \frac{x_f}{x_r + x_f} \times 100$$

capacity and flexibility which such subdivision always introduces. Without, therefore, pursuing this phase of the matter further it is at once evident that the hydroelectric station has use for reactance, as by its means the whole station may be operated in multiple while at the same time the several sections may be protected from each other and each section from the individual lines which it feeds. Troubles may be localized or isolated practically where they originate, without communicating their evil effects to other points.

The use of reactance is also often required, especially in older stations, for the protection of apparatus other than the gener-

Digitized by Google

ators, such as oil switches and wiring which have been outgrown by the expansion of the plant but which cannot readily be strengthened or replaced.

The protective and localizing functions of reactance are quite distinct. The former, since all the evil effects of heavy current,—mechanical forces, heating, etc.—are proportional to the square of the current, is measured in terms involving the square of the total reactance; and the latter is measured in terms of the first power of the reactance involved. (See Figs. 1, 2 and 3.)

Unfortunarely the installation of reactance gives rise to in-

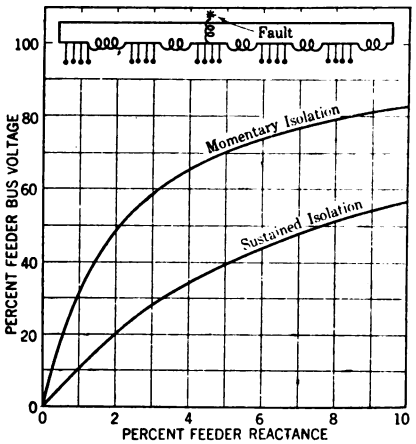


FIG. 3—MOMENTARY AND SUSTAINED ISOLATION BY FEEDER REACTANCE

Momentary generator reactance—20%
Synchronous generator reactance—50%
Bus reactance—4%
20 generators in groups of 4
All reactances based on rating of one generator

creased voltage drops and phase displacements under load conditions which place a limit upon the amount of reactance that can be used. Each installation is in this respect a problem by itself. (See Fig. 4.)

Owing to the different natures of the three load groups above referred to, and to the diverse character of the apparatus and transmission lines required to supply them, it will usually be found that the effective localization of disturbances requires the installation of reactance in two locations; in the bus between sections and in the individual outgoing feeders.

In connection with the bus reactances a new limitation now

Digitized by Google

appears which apparently has not heretofore been recognized, due perhaps to its unimportance in the steam turbine station. I refer to the decrease in the synchronous stability of the station with the installation of reactance in the bus.

There seems to be a somewhat general impression that the addition of reactance increases the synchronous stability. Such, however, is by no means necessarily or even usually, the case. It is a more or less well known fact, which however can be readily demonstrated (See Appendix A) that the synchronizing power between two generators is a maximum with reference to the circuit constants when $x/r = \sqrt{3}$, or $x = 1.732\,r$.

Now consider the constants of a typical hydraulic turbine-driven 25-cycle generator of say 10,000-kv-a. capacity at 12,000 volts. Its armature resistance, is perhaps 0.1 ohm, whereas its reactance, perhaps 20 per cent, would be about 3 ohms per phase. That is we have here $x = 30\,r$. Even allowing for the additional

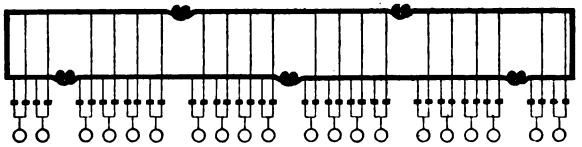


FIG. 4—ARRANGEMENT TO CONTROL BUS REACTANCE CURRENT
By means of selector switches on generators, power transfer through bus reactances may be limited.

resistance of connections, it is obvious that the reactance is already far beyond the point of maximum synchronizing power, and that any addition, either in generator leads or busses, acts to *reduce* rather than to increase the synchronizing power and stability. Between stations widely separated by transmission lines of considerable resistance this condition may of course be reversed.

Let us now consider a system consisting of generators connected in groups, with bus reactances between, which would represent a typical large hydroelectric station. In such a system the resistances would be small compared to the reactances, and hence will be neglected in the following consideration. (See Appendix B). Let us assume this system in full operation, each group of generators supplying its own feeders, when there comes a sudden complete interruption of the load on one group. For convenience let us call this group A and the remainder of the

Digitized by Google

system group B. For simplicity let the power factor of the interrupted load be such that the terminal voltage plus armature reactance drop numerically equals terminal voltage. Also assume that the turbine gates of group A remain open. It is apparent that to determine what happens we must consider the transient conditions.

At the instant of interruption the conditions are as shown in Fig. 5.

E_0 is the terminal voltage of group A and $-E_0$ of group B before interruption.

E is the terminal voltage of A at the instant after interruption.

$E_1 = I_0 X_1$ is the drop due to load current I_0 through X_1, the internal reactance of group A. The interrupted load is

$$P_0 = E_0 I_0 \cos \theta$$

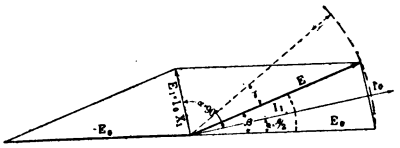


FIG. 5—VECTOR DIAGRAM OF STABILITY CONDITIONS

At the instant after interruption the terminal voltage of group A leads that of group B by angle β thus producing the voltage E_1 which is available to circulate a current through $x = x_1 + x_2 + x_3$ the total reactance of groups A and B and the bus, in series. The magnitude of this initial circulating current is,—

$$I_1 = \frac{E_1}{x_1 + x_2 + x_3} = \frac{E_1}{x} = I_0 \frac{x_1}{x} \qquad (1)$$

and as it lags 90 degrees behind E_1 it is in the same phase position as I_0 and has a component in phase with E and in phase oppostion with $-E_0$. It is synchronizing current, accelerating group B and retarding group A.

The initial synchronizing power flowing from group A to group B then is

$$P_1 = E I_1 \cos \theta = E I_0 \frac{x_1}{x} \cos \theta = P_0 \frac{x_1}{x} \qquad (2)$$

Digitized by Google

or the synchronizing power immediately following the interruption is $\frac{x_1}{x}$ of the interrupted load.

The conditions then are as follows: The interrupted power P_0 is still pouring into the generators of group A from the turbines. Of this, $P_1 = P_0 \frac{x_1}{x}$ is leaving the generators and accelerating group B, but the remainder $P_2 = P_0 - P_1$ is being applied to accelerate group A. As the ratio of the inertia of group A to that of group B, is less than that of P_2 to P_1, group, A accelerates faster than group B. This results in an increase, which we will call, γ, in the phase displacement of group A with respect to B and causes an increase in the synchronizing power, according to the equation,—

$$p_1 = \frac{E^2 \sin(\beta + \gamma)}{x} \qquad (3)$$

As p_1 increases, p_2 $(= P_0 - p_1)$ decreases but still has a positive value until the displacement reaches a point where $p_1 = P_0$. At this point all the power input from the turbines to group A is being passed on to group B and the acceleration of group A with respect to group B ceases. But the acceleration now being zero, the speed with respect to group B is a maximum. From this point on p_2 becomes negative, that is, the energy stored in the flywheel effect of group A is taken out and passed on to group B causing A to retard. Its velocity, however, with respect to B being still positive, the phase displacement continues to increase, with a resultant increase of the synchronizing power, p_1, which is now supplied from the stored energy of A plus the turbine input P_0.

This increase in p_1 and γ continues until the speed of group A with respect to group B is brought back to zero, that is until both groups are again momentarily running at the same speed, when γ is at its maximum value.

The maximum values reached by p_1 and γ are difficult to exactly calculate. While a rigid mathematical determination of their values might be of academic interest, an approximate solution is of more practical value. Attacking the problem therefore in a practical way approximate values may be arrived at with various degrees of accuracy in the following ways.

Digitized by Google

First, if we assume that the maximum value of p_1 is the same as it would have been, had it been reached by a straight line instead of a sine curve; that is, if p_1 and $(\beta + \gamma)$ are united by a straight line instead of a sine function, we can apply the usual law of the suddenly applied force, that maximum deflection is twice that due to the same force slowly applied, or maximum reactive force twice the suddenly applied force.

The suddenly applied force here is P_2, (strictly the torque produced by P_2). The maximum reactive force then is $2P_2$ which added to the initial force P_1 gives the total resultant force (synchronizing power) at maximum deflection. The maximum deflection or angular displacement then is approximately

$$(\beta + \gamma)\max = \sin^{-1} \frac{P_1 + 2P_2}{\frac{E^2}{x}} = \frac{(P_1 + 2P_2)x}{E^2} \qquad (4)$$

Second, if we neglect the slight change in speed so that we can put torque proportional to power we can immediately equate the work done on group A by the turbine with that done by group A on group B during the time that γ is increasing, as at the instant when γ is a maximum the speeds of the two groups are again the same and all the energy put into group A has been taken out again. (This is strictly true only if group B be of infinite inertia, so that its speed cannot change, but is relatively true in any case.) Since the speed is assumed constant we have torque $T = P_0$ times a constant K or $T = K P_0$, whence

Work done on group A is

$$W_e = T \gamma_m = K P_0 \gamma_m \qquad (5)$$

Work done by group A is

$$W_i = K \int_{\beta}^{(\beta + \gamma_m)} p_1 \, d\gamma$$

$$= K \int_{\beta}^{(\beta + \gamma_m)} \frac{E^2}{x} \sin(\beta + \gamma) \, d\gamma$$

$$= \frac{K E^2}{x} [\text{vers}(\beta + \gamma_m) - \text{vers}\ \beta]$$

$$= \frac{K E^2}{x} [\cos \beta - \cos(\beta + \gamma_m) \qquad (6)$$

Digitized by Google

Equating

$$W_e = W_i = K P_0 \gamma_m = \frac{K E^2}{x} [\cos \beta - \cos (\beta + \gamma_m)]$$

$$\frac{P_0 x}{E^2} \gamma_m + \cos (\beta + \gamma_m) = \cos \beta \qquad (7)$$

The values of P_0, x, E and β being known, this equation can easily be solved for γ_m, the maximum value of γ, by trial and error.

Third, the result can be attained by arithmetic integration, which practically must be employed when hydraulic conditions enter into the calculations, as in the case where there are long penstocks. In an actual case the first method gave $(\beta + \gamma_m) = 48.3$ deg., the second method 46 deg. and the third 46.05 deg.

The synchronizing power p_1 reaches its maximum value when $(\beta + \gamma)$ becomes equal to $\frac{\pi}{2}$ radians or 90 deg. Therefore if $(\beta + \gamma)$ exceeds the value $\frac{\pi}{2}$, p_1 begins to decrease, the condition becomes completely unstable and the two systems will fall out of step. It is therefore essential, if this condition is to be avoided, that the reactance be so chosen with reference to the other conditions that $(\beta + \gamma_m)$ shall always be less than $\frac{\pi}{2}$ radians.

A mathematical expression for relative stability may be derived in terms of the angular electrical phase displacement of two systems when subjected to a certain definite load disturbance. Since sudden loss of full load of one group is possible, and may be considered the worst possible case, it appears desirable to use this condition as the criterion of stability. For any given case the maximum, or 100 per cent, stability will exist with zero external reactance; and zero stability, or complete asynchronism will occur when the reactance is such that the maximum phase displacement due to sudden loss of full load becomes equal to $\frac{\pi}{2}$ radians or 90 deg. (assuming γ negligible compared to x). The expression for relative stability then becomes

$$\text{Per cent stability} = 100 \left(1 - \frac{\gamma_m}{\frac{\pi}{2} - \beta} \right)$$

Digitized by Google

It remains to be shown that instability of synchronism is a practical limitation. As a typical illustration I have assumed a plant consisting of 20 units of 10,000 kw. each, connected in five groups of four generators each, separated by bus reactances. Figs. 6 and 7 show the stability conditions when connected, respectively, to a closed ring, an open ring, and a reactance bus, expressed in terms of the maximum angle of phase difference due to sudden total loss of load of one group. Fig. 8 shows the

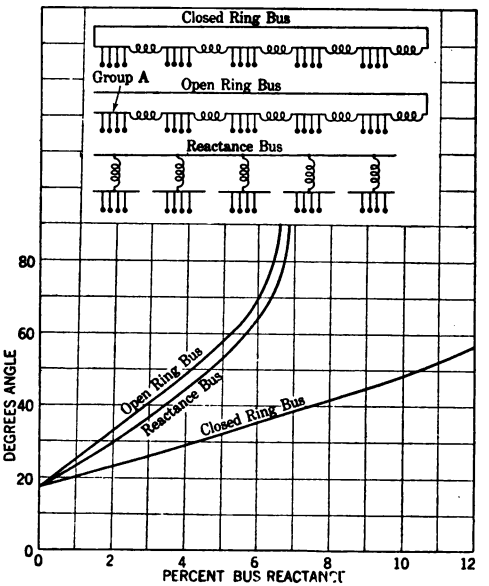


FIG. 6—MAXIMUM ANGULAR PHASE DISPLACEMENT ON SUDDEN LOSS OF LOAD OF ONE GROUP

Generator reactance—20%
20 generators in groups of 4
Bus reactance—4%
Bus reactance based on rating of one generator
Load power factor 100%

comparison of protective effect and stability of the reactance bus scheme, both expressed in per cent. These curves are calculated according to the first method previously stated, and are therefore approximate. They show clearly that the values of reactance which will cause instability are about the same as those often found desirable for protective purposes.

Even though the amount of external reactance installed is not sufficient to cause complete instability, serious results may, nevertheless, result. The period of the oscillation, t, depends

Digitized by Google

upon the moment of inertia of the rotating machinery, the speed of rotation and other constants, and for small oscillations is given approximately by the formula

$$t = 2\pi\sqrt{\frac{W r^2 S Z}{K_g n E^2 p}} \qquad (8)$$

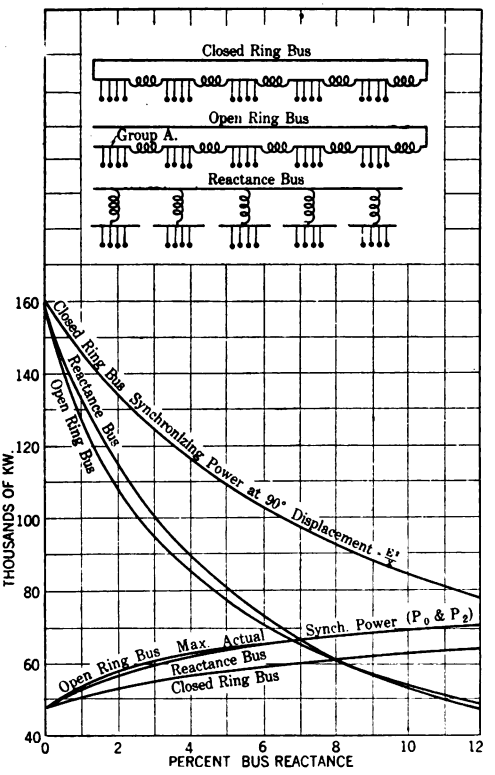


FIG. 7—MAXIMUM POSSIBLE AND MAXIMUM ACTUAL SYNCHRONIZING POWER ON LOSS OF FULL LOAD OF ONE GROUP

Generator reactance—20%
20 generators in groups of 4
Bus reactance based on rating of one generator

Where W = weight of revolving parts of generators of one group.
r = radius of gyration of generators.
S = speed of rotation in rev. per min.
Z = impedance of circuit.
n = number of phases.

Digitized by Google

E = volts per phase to neutral.
p = number of field poles
g = acceleration of gravity.
K = a constant (= 3.5 when W, r and g are in English measure).

In the specific case under consideration.

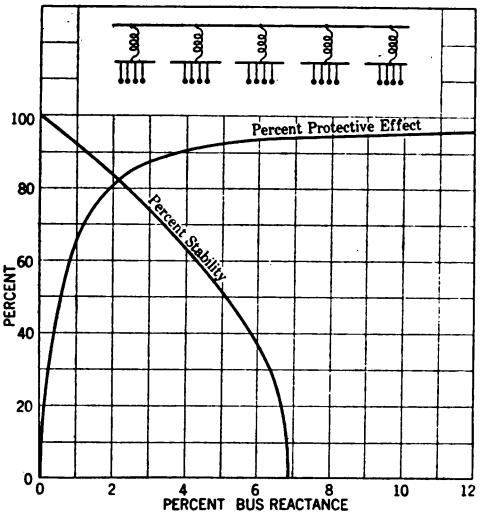


FIG. 8—COMPARISON OF PROTECTIVE EFFECT AND STABILITY OF REACTANCE BUS SCHEME

Generator reactance—20%
20 generators in groups of 4
All reactance based on capacity of one generator
Explanation—if reactance exceeds 6.9%, loss of total load on one group will result in complete desynchronizing of the group affected

Per cent protective effect $= 100\left(1 - \frac{x_0^2}{(x_0 + x_2)^2}\right)$ (See Fig. 1)

Per cent stability $= 100\left(1 - \frac{V_m}{\frac{\pi}{2} - \beta}\right)$

Wr^2 = 5,500,000 lbs. ft.^{2} per generator, or 22,000,000 lbs. ft.^{2} per group.
S = 187.5 rev. per min.
Z = x (since r is negligible compared to x)
n = 3
E = 6930 (12,000 volts between terminal)
p = 16.
K = 3.5.

Digitized by Google

The periods of the oscillation for the various values of bus reactance considered are then shown in Fig. 9. The initial values are those determined by the instantaneous reactance and the final values by the synchronous reactance. From Figs. 6 and 9 it is seen that the addition of reactance increases both the period and the amplitude of the hunting oscillation. Both of these effects tend to aggravate the accompanying gate movements, so that under suitable conditions very considerable turbine gate

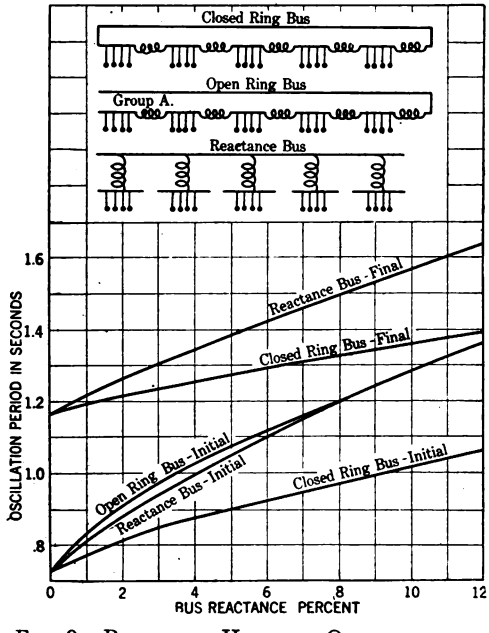


FIG. 9—PERIOD OF HUNTING OSCILLATION

Generator—12,000-volts—187.5-rev. per min.—25-cycles—3-phase
20 generators in groups of 4—Wr^2—5,500,000 lbs. ft.^{2} each
Bus reactance based on rating of one generator
Generator reactance—momentary 20%—synchronous 50%

movements may result from and accompany the hunting oscillation. As turbine governors operate on the centrifugal principle, the most rapid gate movement occurs when the speed is at its maximum departure from normal, which is at the instant when the phase displacement and synchronizing power are passing through their average values, that is, when the angle of oscillation, γ is passing through zero.

In plants with long penstocks, when the turbine gates move,

Digitized by Google

the first effect is the opposite of that intended. That is, as the gates start to close, the sudden retardation of the penstock velocity creates additional pressure, which momentarily increases the power delivered to the turbine, thus causing acceleration of the turbine where retardation was intended.

In the particular case chosen for illustration, the turbines are assumed supplied through penstocks 322 feet (98.1 m.) long and 63 sq. ft. (5.85 sq. m.) in area under an effective net head of 189 feet (57.6 m.). (These values are chosen for convenience in calculation. They are not intended to represent exactly any actual case.)

Assuming an efficiency of 80 per cent the discharge will be

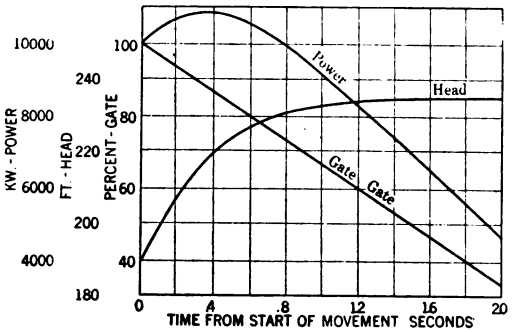


FIG. 10—POWER AND HEAD DURING CLOSING OF WATER-WHEEL GATES

Time for complete stroke 3 seconds
Length of penstock—322 feet
Area of penstock—63 sq. ft.
Net head—189 ft.

$$\frac{10{,}000 \times 550}{0.746 \times 62.5 \times 189 \times .80} = 782 \text{ cubic feet (22.13 cu. m.) per}$$

second and the penstock velocity will be

$$\frac{782}{63} = 12.4 \text{ feet per second. (3.78 m. per sec.)}$$

With the governors so adjusted as to make a complete stroke in 3 seconds, the mean effective increase in head while the gates are closing will be

$$h_a = \frac{L \times V}{g \times t} = \frac{322 \times 12.4}{32.2 \times 3} = 41.3 \text{ feet (12.58 m.)}$$

Digitized by Google

The increase in head increases the velocity through the gates and the power for each position of the gate is increased above what it would be at a constant head. Fig. 10 shows the values of head and power for the above case during the first two seconds of the closing stroke. These curves show that for 0.77 of a second the power is highe· than the initial value, although

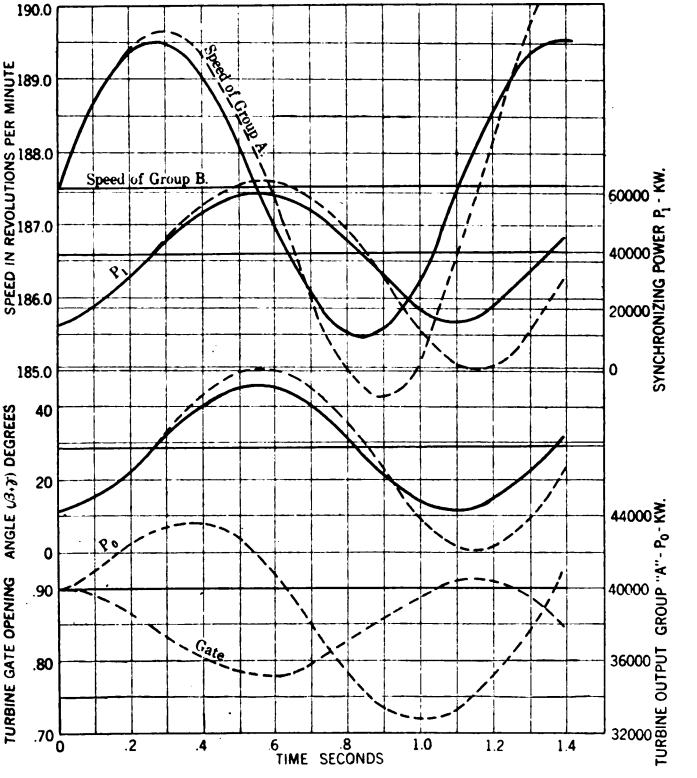


FIG. 11—POWER SURGES OR HUNTING BETWEEN WATER-WHEEL DRIVEN GENERATORS DUE TO REACTANCE

Full lines—wheels without penstocks
Dotted lines—wheels with penstocks

during this time the gate has closed to 74.3 per cent of its full open position. Thus it is seen that the oscillation of the gate, a quarter cycle out of phase with the synchronizing power oscillation, serves to supply positive and negative power to the oscillating system, just at the proper times to keep it in oscillation. If the power supplied in this manner exceeds the losses due to

Digitized by Google

the oscillation, the hunting will increase until the supply and the losses become equal Fig 11 illustrates the conditions graphically for the above specific case as worked out by arithmetic integration, showing clearly the time-phase relations between the various actions.

The addition of reactance, therefore, in such a location that it may be encountered by the synchronizing current between generators or between groups of generators, produces two results as affecting the synchronous stability of the system. First, it increases the amplitude of the hunting oscillation. This makes it more likely that the two systems will twist out of the synchronism on the first quarter cycle of the oscillation. Second, it increases the period of the hunting oscillation. The combined effect of the increased amplitude and the increased period causes a wider range of turbine gate movement. The resulting oscillation of the gates may cause very appreciable power impulses, in time with the hunting oscillation, and in such phase relation thereto as to maintain the oscillation indefinitely or possibly to increase it to the point where asynchronism finally results.

In a certain case where there were 16 generators connected in groups of four in an open ring system with 12 per cent reactance between groups, capacity of generators about 9000 kw., 12,000 volts, a surge was started by the sudden rejection from the end bus section of a load of about 20,000 kw., and continued until the circuit breakers were opened, separating the groups. The surging did not confine itself to the section in trouble and the immediately adjoining section but was communicated with practically unreduced violence to all the sections. Wattmeters connected in the bus reactance circuits showed more than full scale —12,000 kw.—at each oscillation, and this power surged back and forth between generator groups about 60 times a minute until the switches were opened. Overload relays in the circuits set for one second time limit failed to trip the switches owing to the rapid reversals of the surges. These surges were accompanied by oscillations of the turbine gates over a range of about 10 per cent of full stroke.

The amount of reactance required to create such conditions of instability as herein described is of the same order of magnitude as that required for protective and localizing purposes. Such being the case it follows that no installation of current limiting reactance can safely be undertaken, at least in a hydroelectric plant, without a thorough investigation of the effect of such installation upon the synchronous stability of the station.

Digitized by Google

APPENDIX A

Proof That Maximum Synchronizing Power Occurs When $\frac{x}{r} = \sqrt{3}$.

Let E be the voltage of one generator or group.
Then $-E\ (a + j\,b)$ will be the voltage of the other generator (motor) or group, $\frac{b}{a}$ being the tangent of the phase angle between them.
The resultant or vector sum of these two voltages E_1, is that which causes current to flow and has the value

$$E_1 = E - E\,(a + j\,b) = E\,(1 - a - j\,b) \tag{9}$$

The current which flows then is,

$$I = \frac{E\,(1 - a - j\,b)}{r - j\,x}$$

$$= \frac{E\,(r + j\,x)\,(1 - a - j\,b)}{r^2 + x^2}$$

$$= \frac{E}{r^2 + x^2}[r\,(1 - a) + b\,x + J\,\{(1 - a)\,x - b\,r\}] \tag{10}$$

The synchronizing power then is,

$$P_s = I\,[-E\,(a + j\,b)] = -\frac{E^2}{r^2 + x^2}[a\,r\,(1 - a) + a\,b\,x + b\,\{(1 - a)\,x - b\,r\}]$$

$$= -\frac{E^2}{r^2 + x^2}[a\,r - a^2\,r + a\,b\,x + b\,x - a\,b\,x - b^2\,r]$$

$$= -\frac{E^2}{r^2 + x^2}[a\,r + b\,x - r\,(a^2 + b^2)]$$

but $a^2 + b^2 = 1$ and $b = \sqrt{1 - a^2}$

Whence $P_s = -\frac{E^2}{r^2 + x^2}[a\,r + x\,\sqrt{1 - a^2} - r]$ (11)

Digitized by Google

Differentiating with respect to a and equating to 0,

$$\frac{dP_s}{da} = -\frac{E^2}{r^2 + x^2}\left[r + \frac{\frac{x}{2}(-2a)}{\sqrt{1-a^2}}\right] = 0$$

$$r\sqrt{1-a^2} = xa$$

$$r^2(1-a^2) = x^2a^2$$

$$r^2 - r^2a^2 = x^2a^2$$

$$a^2 = \frac{r^2}{r^2 + x^2}$$

$$a = \frac{r}{\sqrt{r^2 + x^2}} \qquad (12)$$

Substituing this value of a in equation (**11**) gives the equation for the maximum value of P_s with respect to the phase angle:—

$$P_s(\max) = -\frac{E^2}{r^2 + x^2}\left[\frac{r^2}{\sqrt{r^2 + x^2}} + x\sqrt{1 - \frac{r^2}{r^2+x^2}} - r\right]$$

$$= -\frac{E^2}{r^2 + x^2}\left[\frac{r^2}{\sqrt{r + x^2}} + \frac{x^2}{\sqrt{r^2 + x^2}} - r\right]$$

$$= -\frac{E^2}{r^2+x^2}\left[\sqrt{r^2 + x} - r\right]$$

$$= -E\left[\frac{1}{\sqrt{x^2 + r^2}} - \frac{r}{x + r^2}\right]$$

$$= -E^2\left[\frac{1}{r\sqrt{\frac{x^2}{r^2} + 1}} - \frac{1}{r\left(\frac{x^2}{r^2} + 1\right)}\right] \qquad (13)$$

Digitized by Google

Different ating with respect to x/r and equating to 0,

$$\frac{dP_s}{d\left(\frac{x}{r}\right)} = \frac{-\frac{1}{2}\cdot 2\cdot\frac{x}{r}}{r\left(\frac{x^2}{r^2}+1\right)^{3/2}} - \frac{-2\,\frac{x}{r}}{r\left(\frac{x^2}{r^2}+1\right)^2} = 0$$

$$= -\frac{\frac{x}{r}}{r\left(\frac{x^2}{r^2}+1\right)^{3/2}} - \frac{\frac{2x}{r}}{r\left(\frac{x^2}{r}+1\right)^2} = 0$$

$$\frac{2}{\sqrt{\frac{x^2}{r^2}+1}} = 1$$

$$\sqrt{\frac{x^2}{r^2}+1} = 2$$

$$\frac{x^2}{r^2}+1 = 4$$

$$\frac{x^2}{r^2} = 3$$

$$\frac{x}{r} = \sqrt{3} \qquad (14)$$

The writer wishes to acknowledge indebtedness in connection with the above to Mr. H. R. Woodrow.

APPENDIX B

Effect of Neglecting Resistance of Generators and Connections

The equation for maximum synchronizing power is,

$$P_s\,(\max) = -E^2\left(\frac{1}{r\sqrt{\frac{x^2}{r^2}+1}} - \frac{1}{r\left(\frac{x^2}{r^2}+1\right)}\right) \qquad (13)$$

from which values of P_s (max) can be determined for assumed values of x and r

If we put $r = 0$ this equation becomes indeterminate.

Digitized by Google

The general equation for P_s is,

$$P_s = -\frac{E}{r^2 + x^2}\left(a\,r + x\sqrt{1 - a^2} - r\right) \qquad (11)$$

putting $r = 0$

$$P_s = -\frac{E^2}{x^2}\left(x\sqrt{1 - a^2}\right) = -\frac{E^2}{x}\sqrt{1 - a^2} \qquad (15)$$

differentiating with respect to a and equating to 0.

$$\frac{d\,P_s}{d\,a} = -\frac{E^2}{x}\left(\frac{a}{\sqrt{1 - a^2}}\right) = 0$$

whence $a = 0$

Substituting in (15)

$$P_s\,(\max) = -\frac{E^2}{x}\sqrt{1 - 0^2} = -\frac{E^2}{x} \qquad (16)$$

Also since when $a = 0$ the phase angle $= \frac{\pi}{2}$ radians or 90 degrees it follows that when r is zero the maximum synchronizing power occurs at a phase angle of 90 degrees.

The following table serves to illustrate the comparatively small error in the maximum synchronizing power due to neglecting the resistance in a case where there are two groups of four 10,000-kv-a. generators of 20 per cent individual reactance, 12,000 volts, 3 phase, 187.5 rev. per min., for various values of bus reactance between the two groups.

Bus reactance per cent.	Total reactance		Total resis.	Max. syn. power resis. considered	Max. syn. power res. neglected	— Per cent error
	per cent	Ohms				
0	10	1.44	0.042	97,300 kw.	100,000 kw.	2.77
2	12	1.73	0.048	81,200 "	83,200 "	2.47
4	14	2.02	0.054	69,400 "	71,300 "	2.73
6	16	2.30	0.060	61,300 "	62,600 "	2.12
8	18	2.59	0.066	54,300 "	55,600 "	2.40
10	20	2.88	0.072	48,800 "	50,000 "	2.46
12	22	3.17	0.078	44,400 "	45,500 "	2.40
15	25	3.60	0.087	39,000 "	40,000 "	2.57
20	30	4.32	0.102	32,700 "	33,300 "	1.84

It is therefore evident that no appreciable error is made by neglecting the resistance in calculating the values for the first half cycle of the oscillation. The resistance would of course have to be considered in calculating the attenuation during subsequent cycles.

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 14, 1917.

Copyright 1917. By A. I. E. E.
(Subject to final revision for the Transactions.)

PROTECTION OF TRANSFORMER NEUTRALS AGAINST DESTRUCTIVE TRANSIENT DISTURBANCES

BY MAX H. COLLBOHM

ABSTRACT OF PAPER

The paper points out the danger to which the neutral point of transformers, connected to long distance transmission lines, are exposed through the building up of excessive potentials at this point under conditions of atmospheric lightning. This is due to the fact that the neutral point in a bank of Y-connected transformers acts as a reflection point for all the waves that are produced by induced lightning, which waves, at the place of origin, have the same amplitude and sign, and, therefore, travel with equal speed, considering that the impedance of line and transformer is the same for each phase. The three waves meeting at the neutral point build up to three times their individual potential at that place, thereby producing excessive potential stresses, and, according to experience, destruction of bushings and windings. The author recommends the installation of lightning arresters at the neutral point to provide a discharge path for the excess potential, which, according to measurement with a spark gap, may reach values of 350,000 volts, and higher.

IT IS a well established practise to protect the low-tension windings of a transformer through a spark gap, against the excessive potentials induced upon it through capacity effects between high tension and low-tension windings under abnormal voltage conditions on the high-voltage side. There also exists, however, a distinct danger to the high-voltage side which is not generally recognized and which cannot be guarded against by the ordinary types of arresters of American manufacture, such as the electrolytic and multigap types, installed in the usual way. This danger is evident from the following consideration:

If during a lightning storm a discharge takes place from a cloud above a transmission line, the electrostatic charge, previously induced by this cloud in equal quantities and like polarity on all three wires of a three-phase line, is suddenly set free and travels in both directions along the line. Inasmuch as for all practical purposes the three wires of the same line offer the same impedance, and as this is also true of the main power trans-

Manuscript of this paper was received September 15, 1916.

Digitized by Google

formers on either end of the line, the speed of propagation of the released electrostatic charge, or more correctly that portion of it which has not been discharged over the insulators or through corona, is exactly alike in all three wires. Consequently the neutral point of the transformer, if connected in Y, constitutes the reflection point for all these traveling waves. If the potential of this traveling wave after having reached the station is below the value for which the arresters have been set it will pass through the transformers, and as the charges from all three wires meet at the neutral point they build up to three times their individual potential at that place. Although the potential difference to ground of each individual charge may be below the safe electrostatic stress of the transformer winding and terminal bushing, the combined effect of the triple voltage is likely to produce disastrous results.

The writer was confronted with this condition in the operation of the Peninsular Power Co's. system at Iron Mountain, Mich., where the 66,000-volt step-down transformers in the Iron River substation showed repeatedly momentary arcing from the neutral transformer terminals to the case, a distance of three feet (0.91m.) In one instance the arc formed between the neutral lead under oil and the transformer iron resulting in the burning off of said lead.

In order to provide a discharge path for this dangerous potential a multigap arrester will be installed at the neutral point and adjusted to discharge at 42,000 volts. This high-voltage setting for the arrester became necessary for the reason that the system operates with the transformer neutral at the generating station grounded over a metallic resistance to avoid service interruption in case of accidental grounds on one of the line wires and which under such conditions, otherwise harmless, would produce a potential difference of 38,000 volts between transformer neutral and ground. A multigap arrester was chosen in place of an electrolytic arrester in order to avoid the inconvenience of providing for the necessary special arrangement and constant attendance for the regular charging of the latter.

On account of the urgent need for protection of the substation transformer neutral and the present inability of the manufacturers to effect short time deliveries, a makeshift arrangement has been used to serve until the multigap arrester is received. This arrangement consists of two zinc

Digitized by Google

balls 5 in. (127 mm.) in diameter, set 6 in. (152.4 mm.) apart, each supported by an iron rod and connected to the neutral point and ground, respectively, thus forming a relief gap for the transient excess potential. The sphere spark gap was chosen on account of its greater sensitiveness under sudden impulses as compared with the needle gap. The spheres have been made of zinc on account of the arc extinguishing tendency of this metal.

This arrangement has worked very well during recent lightning storms, when discharges over this spark gap have repeatedly been observed. This proves that protection against the above-mentioned transient disturbances can be obtained by a shunted spark gap. It is of interest to note that the spheres were originally set 12 in. (304.8) mm. apart by error and even with this wide setting the previously mentioned discharges have been observed, indicating the surprising potential difference of about 350,000 volts between neutral and ground.

It should be noted that the trouble occurred only on the transformer neutral in the substation, while no disturbances of this nature were observed in the generating station where the metallic ground rheostat between transformer neutral and ground served to drain off these transient charges.

The danger from this source is only present in Y-connected transformers where the neutral acts as a reflection point. If delta connection is used on the high-tension side, the incoming charge divides at each corner of the delta, one-half going into one transformer and the other half going into the other transformer. The middle point of each transformer will in this case be the reflection point, but the accumulation of potential at this place will, therefore, not be greater than that of the original charge on each line wire at the transformer terminal. This statement, however, must not be taken to dispute the fact that potentials higher than that possessed by the orignal charge at the transformer may exist within the transformer winding, due to the piling up of potential through reactance under high frequency or steep wave fronts. However, as experience proves that the electrostatic charges actually pass through the transformer and build up at the neutral point to destructive potentials, it appears that their wave front has become less steep, due to the impedance of the transmission line between the point of lightning discharge and the transformer station. From this consideration it would

Digitized by Google

seem that lines of greater lengths should be more subject to this danger of potential rise at the neutral than those of shorter lengths where the impedance may not be great enough to flatten out the transient wave front sufficiently to permit of its passing through the windings. In this latter case, however, danger is present from abnormal potential rises within the transformer due to reactance as mentioned before.

From the foregoing it is evident that protection must be provided for the neutral point of transformer banks, especially on long lines. Additional protection can be obtained through the installation of condenser arresters, manufactured at present in Europe only, on the line side of the transformer leads, as they tend to absorb all transient charges having steep wave fronts or high frequency and thereby prevent, or at least reduce, the danger from abnormal voltage rises within the windings.

Digitized by Google

To be discussed at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 15, 1917. Presented before the Urbana Section May 4, 1916.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

CORONA AND RECTIFICATION IN HYDROGEN

BY J. W. DAVIS AND C. S. BREESE

ABSTRACT OF PAPER

The results of an investigation of the corona discharge between co-axial cylinders in an atmosphere of hydrogen are given in this paper.

Both direct and alternating electromotive forces were used. The characteristic behavior of the corona is given by means of curves, photographs and oscillograms.

The corona discharge in hydrogen was found to differ from that in air in the following particulars:

The discharge from a negative wire was found to differ widely from a positive wire in the magnitude of the voltage necessary to start the discharge in the shape of the volt-ampere characteristic and also in the stability of the discharge.

Corona in hydrogen between concentric cylinders is shown to be a practicable method for rectifying high potential alternating currents.

The apparent evidence of ionization potential gradients at the surface of the tube and the general character of the visual phenomena are discussed.

A brief statement of conclusions is given.

WHEN a sufficiently high potential difference is impressed between two parallel wires, or a wire and concentric cylinder, separated by air or some other gas, this gas which for low potential gradients is a very good insulator breaks down and becomes a partial conductor. The phenomena connected with this character of conduction through gases are known collectively by the name corona. The failure of the gaseous dielectric separating the metallic conductors is made evident by a flow of current from one conductor to the other, by a power loss and, in practically all cases, by the appearance of light at either one or both conductor surfaces. In some cases light appears in the intervening space.

Since the present theories as to the mechanism of corona formation do not satisfactorily account for all of the observed phenomena it was decided to carry out further investigations in the hope that when enough data were accumulated some theory

Manuscript of this paper was received May 29, 1916.

Digitized by Google

based on fundamental principles and explaining the observed phenomena might be evolved. With this purpose in mind it was attempted to simplify the conditions of corona formation.

A wire and concentric cylinder were used in order to make the field radial and to get away from the secondary effects due to the high intensity electric field surrounding a second wire. Hydrogen was used as the dielectric in order to minimize the effects due to changes in the chemical constitution of the gas. When air is used as the dielectric the formation of ozone may produce marked changes in the voltage necessary for corona formation. Continuous potential was used in order to separate the effects accompanying a discharge from a positive wire to a negative tube from those which are characteristic of the discharge from a negative wire to a positive tube.

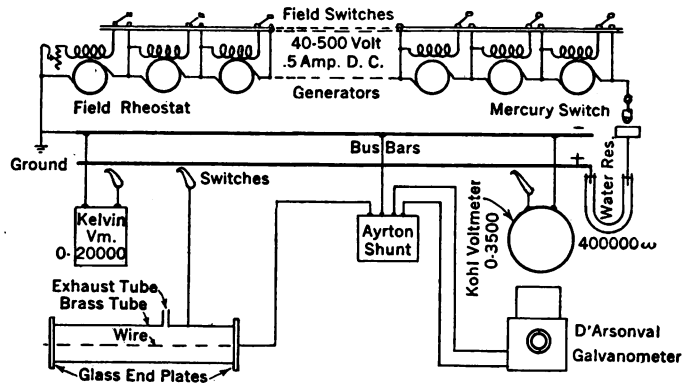


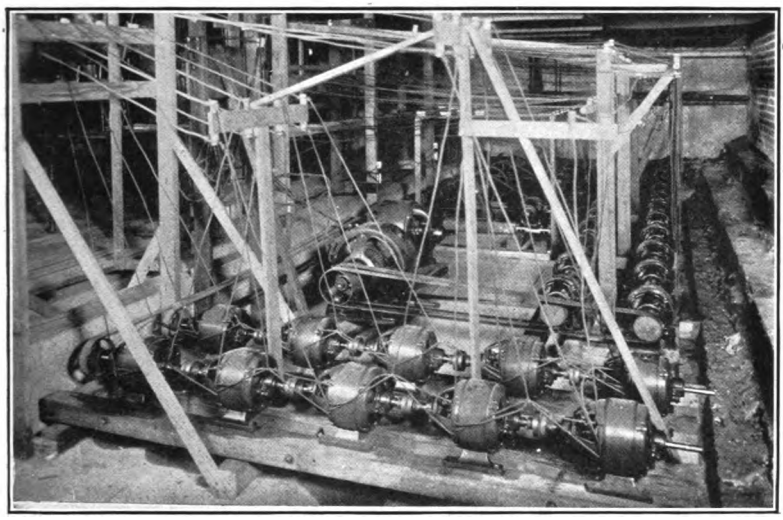
FIG. 1—DIAGRAM OF CONNECTIONS

APPARATUS

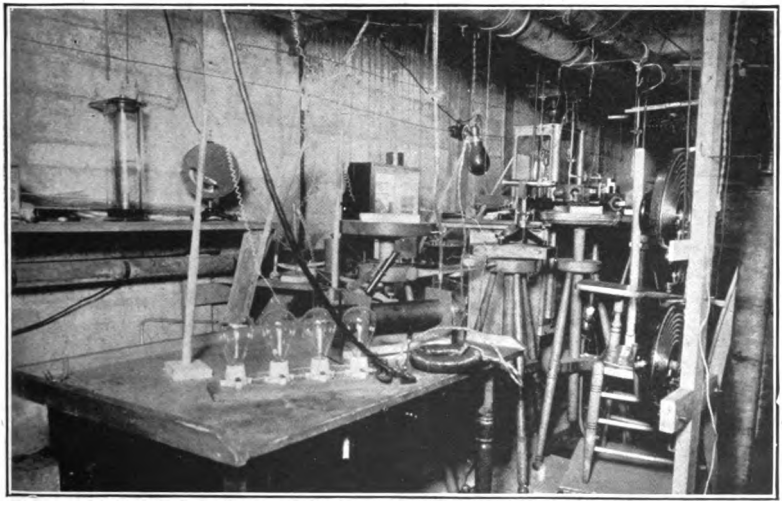
The continuous voltage used in these investigations was obtained by means of a battery of forty 500-volt 250-watt continuous-current shunt-wound generators connected in series.

These machines are divided into two sets of ten machines each and one set of twenty machines, each set being driven by belt-connected continuous-current shunt motor. The generators are mounted on insulating bases and the shafts of the separate machines are connected by insulating couplings. In the newer part of the installation one terminal of each machine is permanently connected to the frame of that generator in order definitely to limit the strain on the machine insulation to the voltage generated in one armature.

Digitized by Google



GENERATING PLANT



[DAVIS AND BREESE]

CORONA TUBES AND MEASURING APPARATUS

Digitized by Google

Digitized by Google

The field of each machine is connected directly across the armature terminals, a single-pole knife switch being included in the circuit in order that the machine may either be made to generate or to run idle at will. These switches were operated by means of a hard rubber rod approximately eighteen inches in length, since they may be 20,000 volts above earth potential. The generators were run somewhat below rated speed in order to limit, to a safe value, the voltage generated with no external resistance in the field circuit.

The diagrams of connections for the direct-current and alternating-current tests are given in Fig. 1 and Fig. 2 respectively. These are self-explanatory.

Instruments. Voltages were measured with a vertical type

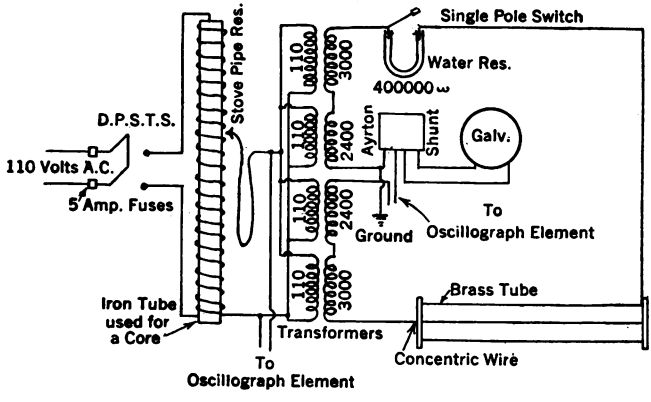


FIG. 2.—CONNECTION DIAGRAM FOR HALF WAVE RECTIFICATION

Kelvin electrostatic voltmeter having ranges of 20,000, 10,000 and 5000 volts and a Kohl electrostatic voltmeter having a range of 3500 volts. These instruments were calibrated from time to time by means of an attracted disk electrometer.* The maximum error in these voltage measurements for a given voltmeter scale reading was less than two per cent. The probable error is less than one per cent.

Currents were measured by means of a d'Arsonval galvanometer and Ayrton universal shunt. These were calibrated as a unit by connecting them in series with a high resistance and a dry cell, the voltage of which has been accurately determined by means of a potentiometer. The voltage of the dry cell was de-

* The theory of the attracted disc electrometer. (TRANS. A. I. E. E., Vol. XXXIII, Part II, 1914, p. 1635.)

Digitized by Google

termined both on open circuit and with the smallest series resistance used in calibrating the galvonometer connected between its terminals as a load. The change in terminal voltage due to the current flowing was, in every case, found to be entirely negligible.

Preparation, Purification and Test of Hydrogen

The hydrogen used in these investigations was prepared by the action of water on hydrone, in a glass containing vessel. Hydrone is the trade name for a sodium lead alloy. This alloy was used in order to reduce the violence of the reaction between the sodium and the water. The hydrogen prepared in this manner was collected over water in a copper vessel.

When it was desired to fill a corona tube with hydrogen the gas was forced out slowly by water pressure. It was passed through drying bottles containing concentrated sulphuric acid and calcium chloride respectively. It was then passed through a hard glass tube containing red hot calcium or calcium hydride. This acted as an effective reagent for removing any traces of oxygen or nitrogen.

The purifying tube was filled with metallic calcium but when this is brought to a red heat in an atmosphere of hydrogen a rapid combination takes place. The hydride formed in this manner must be kept in an atmosphere of hydrogen as it combines with air at room temperature.

From the purifying tube the hydrogen was passed through glass tubing to the corona tube. When a corona tube was to be filled with hydrogen it was exhausted and filled with hydrogen three times in order to remove any traces of air. In every case a Geissler tube was connected to the system while the corona tube was being filled. The spectrum of the gas in this tube was observed at pressures ranging from atmospheric down to the hard X-ray stage. If lines belonging to any spectrum other than that of hydrogen were observed at any pressure the charge was discarded and the corona tube was refilled.

Corona Tube. The results reported in this paper were all obtained with copper wires strung along the axis of a cylindrical brass tube.

The corona tubes were connected to vacuum pumps, air drying bottles, hydrogen apparatus and a mercury manometer by means of a small side tube on each corona tube. One side of the mercury manometer was kept at zero pressure. In this way the

Digitized by Google

manometer readings were made to give the absolute pressure of the gas and were not affected by changes in the barometric pressure. The ends of the brass tubes were closed by means of glass plates through which holes had been ground. Metal bushings having a small hole along the axis were fitted into these holes and secured with red sealing wax. The glass plates were fastened to the ends of the tubes in such a manner that the hole through the metal bushing coincided with the axis of the tube.

The wire on which the corona discharge was to be observed was passed through these bushings. One end was fastened to a spring enclosed in a bottomless glass bottle which was sealed to the end plate so as to surround the bushing. The stopper was removed from this bottle when a new wire was being placed in the tube. When the wire was in place the stopper was sealed tight with half and half wax.* After the wire had been stretched tight the other end was fastened in the metal bushing with red sealing wax. In this way the wire was maintained tight and accurately centered.

The metal bushings were necessary as it was found that with hydrogen a very decided effect was produced on both the corona starting voltage and the volt-ampere characteristics, when corona was allowed to form in the vicinity of these end plates. This effect was due to the breaking down of the gas between the glass and the wire where the wire passed through the glass end plates, as it was not always possible completely to fill this space with wax and at the same time keep the wire within the tube free from the wax, which would start a local discharge.

The wires used in these investigations were carefully cleaned and straightened and then calipered with a micrometer caliper before being placed in the tube. These wires varied in diameter from 0.12 mm. to 1.59 mm. The larger part of the data was taken with the wire in a brass tube 4.45 cm. in diameter but the results were checked with a 7-cm. tube in order to determine whether the size of the tube would affect the nature of the phenomena. No changes due to the size of the tube were noticeable as far the general character of the results and the critical theoretical electric intensity at the surface of the wire are concerned.

*Half and half wax is prepared by melting together approximately equal quantities of bees wax and rosin. The heat should be applied by means of boiling water.

Digitized by Google

Corona in Hydrogen

Throughout the investigation with hydrogen it was found that the breaking down of the dielectric and the appearance of light at the surface of the wire were simultaneous. The voltage necessary to cause these phenomena will be called the critical voltage. The intensity of the electric field at the surface of the wire, under these conditions, computed on the assumption that the field between the wire and the tube is completely determined by the charges on the wire and tube, will be called the critical intensity. The above assumption neglects the possibility of distortion of field due to space charge before the corona starts.

Corona between a positive wire and negative tube will be spoken of as positive corona, while corona between a negative wire and positive tube will be spoken of as negative corona.

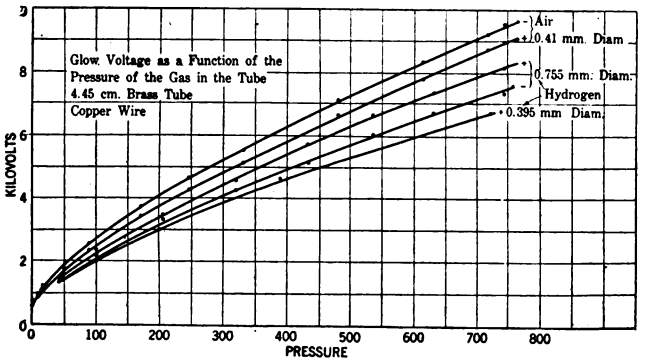


Fig. 3

The + and − signs on the curve sheets refer to the polarity of the wire.

In Fig. 3 are given curves showing the variation of critical voltage with gas pressure for air and hydrogen with two sizes of wire. The curves for air were taken from Farwell's paper (Trans. A. I. E. E., Vol. XXXIII, Part II, 1914, p. 1648.). The curves for air and hydrogen were taken with tubes of the same diameter and therefore may be justly compared. From a casual observation of these curves it is apparent that the law of variation of critical voltage with pressure is essentially the same in the two cases. The curves for hydrogen agree fairly well with Peek's formula when this is put in the form

$$E = E_0 p + C \sqrt{p}$$

Digitized by Google

where E = critical intensity.
p = pressure in per cent of atmospheric pressure.
E_0 and C = constants.

This shows that as far as variation of pressure is concerned, with a given size of wire, the critical intensity for corona in hydrogen obeys Peek's law.

The data so far obtained do not show conclusively that Peek's formula

$$E = E_0 p \left(1 + \frac{b}{\sqrt{pr}}\right)$$

holds for hydrogen when the variation of E with changes of the radius of the wire is considered. In this formula

E = critical intensity.
p = pressure in per cent of atmospheric pressure.
r = radius of wire.
E_0 and b = constants.

The general nature of the results so far obtained however seems to indicate that this formula may hold.

From the curves of Fig. 3 it may be seen that there are two decided differences between the critical voltages for air and hydrogen.

1. With air the positive critical voltage is lower than the negative, while with hydrogen the negative critical voltage is less than the positive. This is true in the case of hydrogen for all sizes of wire and all pressures covered in this investigation.

2. For the same size of wire and the same pressure the critical voltage in hydrogen is much lower than the critical voltage in air.

Characteristic Curves. Characteristic curves for positive corona in hydrogen for two sizes of wire and various pressures are given in Fig. 4 and Fig. 5. These represent the general form of the characteristics for all sizes of wire and all pressures covered in these investigations. The most remarkable points about these characteristics are:—

a. The marked difference between the critical voltage and the voltage at which corona ceases.

b. The difference between the points taken with increasing and those taken with decreasing current.

Digitized by Google

This persistence of corona at voltages less than that necessary to start the discharge has not been observed with air and continuous potentials. (See Bennett TRANS. A. I. E. E., Vol. XXXII, Part II, 1913, p. 1796, for alternating potentials.) If there is any such difference for air its magnitude is certainly very much less than with hydrogen.

This difference between the critical voltage and the voltage at which corona is maintained may be explained by the change

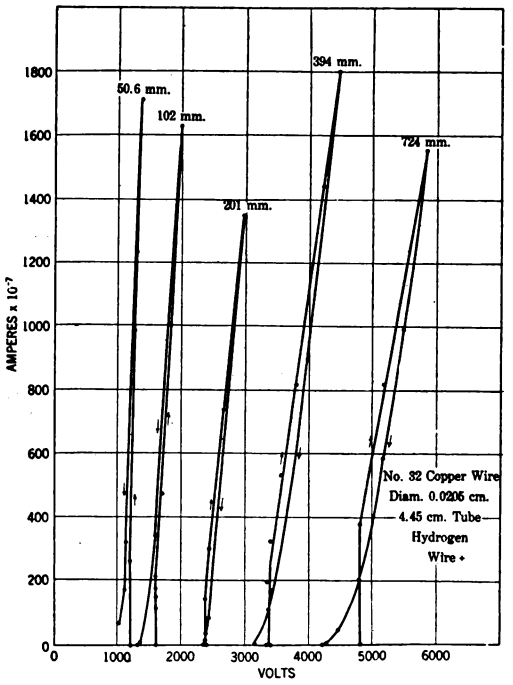


FIG. 4

in the electric intensity (volts per cm.) at the surface of the wire after the corona has been formed. This change of intensity is caused by the space charge due to the positive and negative ions in the space between the wire and the tube. That such a distortion of the electric field exists is well known. The difference between the critical voltage and the voltage at which the discharge ceases is not detected unless all sources of irregular ionization such as rough spots on the wire, high intensity where the wire passes through the glass, etc., are eliminated.

Digitized by Google

The negative corona characteristic curves for a No. 36 B. & S. gage copper wire, 0.121 mm. in diameter, in a brass tube the inside diameter of which was 4.45 cm. are given in Fig. 6. It will be noticed that the shape of these characteristics depends on the gas pressure to a very decided extent.

With this size of wire corona seemed to start in each case with a number of very small bright points on the wire. Usually, however, the negative corona started with an unstable flicker-

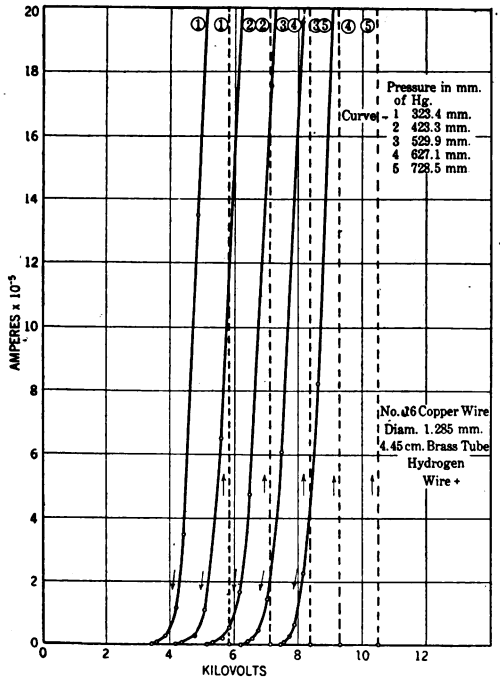


FIG. 5

ing glow along the wire. With an increase of voltage the current gradually increased until a point was reached where the small bright spots combined into one negative bead of the kind described by Farwell (TRANS. A.I.E.E., Vol. XXXIII, Part II, 1914, p. 1631.) This change in formation was accompanied by a large increase in current and a drop in the potential difference between the wire and the tube. This drop in potential difference across the tube was, in a certain sense, due to the resistance in series with the corona tube. The increased current taken by the tube

Digitized by Google

causes a higher drop through the series resistance, which stabilizes the corona discharge and prevents the indefinite increase of current which might result if there were no resistance in the

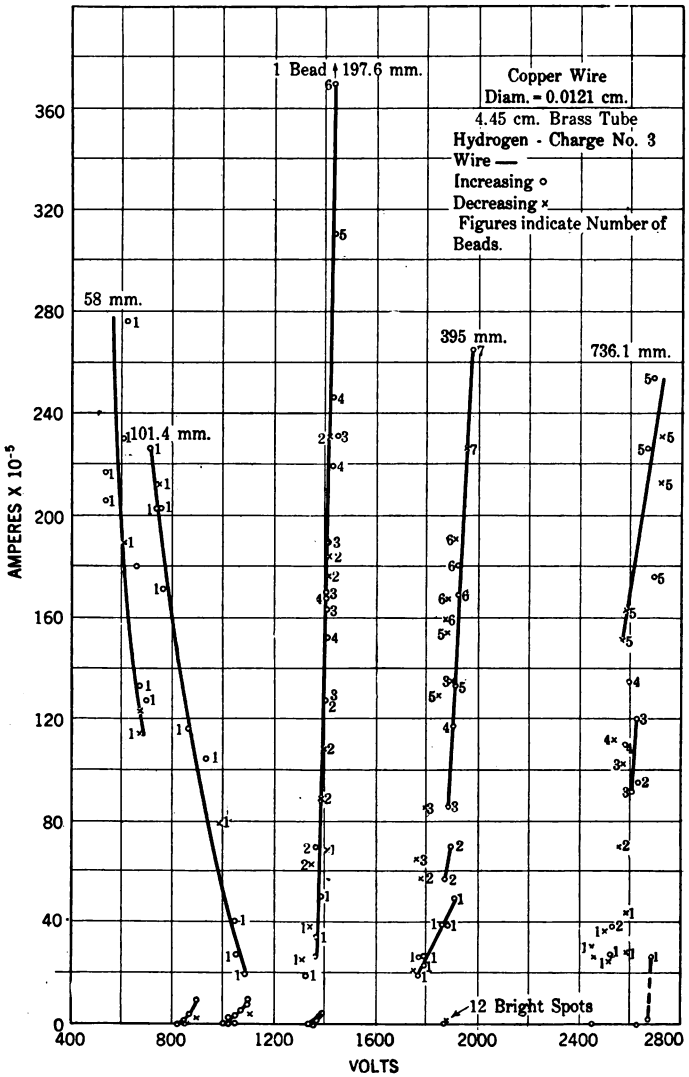


FIG. 6

circuit. The gaps in the curves represent unstable conditions. An increase in the generated voltage caused an increase in the corona, current which was accompanied by either an increase or

Digitized by Google

a decrease of the voltage between the wire and the tube depending on the size of wire and the gas pressure.

It may be noticed that for the lower pressures the corona current-voltage characteristics are similar to the usual arc characteristic. The discharge, however, was not the arc discharge. The arc formed if the machine voltage was sufficiently increased. This was accompanied by a further drop in the voltage between the wire and tube and an entire change in the general appearance of the discharge.

Difference Between Air and Hydrogen. The characteristic curves in Fig. 7 show clearly the difference between the corona in air and in hydrogen. The two curves on the left hand side of

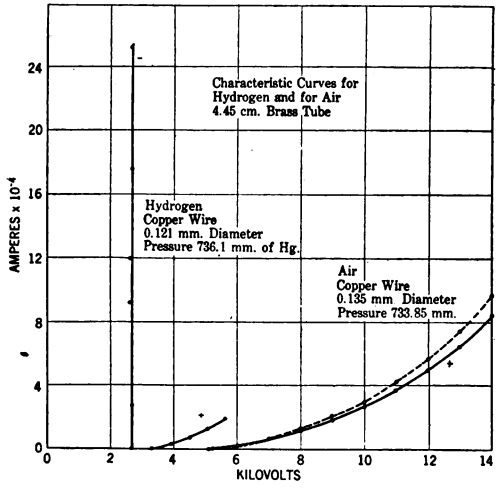


FIG. 7

the sheet refer to hydrogen while the curves on the right were obtained with air. The data for these curves were obtained with wires of approximately the same diameter. The data for corona in air were taken from Farwell's paper. These curves show two differences between air and hydrogen. In air the positive corona starts at a lower voltage than the negative while the reverse is true in case the dielectric is hydrogen. The other and more important difference is the entire dissimilarity of the positive and negative curves with hydrogen. This difference has not been found with air.

It must be remembered that, although the characteristic curves for the wire positive appear to be the same for air and

Digitized by Google

hydrogen, there is a decided difference even in this case as, with hydrogen, the corona was maintained at voltages lower than that necessary to start the discharge.

Rectification

After looking at the above curves it is at once evident that corona in hydrogen between a wire and a tube is an effective means of accomplishing rectification. This is true since large currents may be obtained from a negative wire with voltages which will give little or no current from a positive wire. This rectification may be accomplished with the wire cold and is not a case of rectification by means of a hot cathode. The principle of electron emission from a hot cathode might be used, however, in connection with the corona rectification.

Following up the question of rectification the corona tube was connected to an alternating source of voltage as shown in Fig. 2. A sensitive oscillograph element was connected directly in series with the corona tube and another element was connected across the primaries of the transformers. The oscillograms shown in Figs. 8, 9 and 10 were taken with the connection as shown in this diagram.

Fig. 8 gives the current and voltage curves when an alternating voltage is impressed across a corona tube. The curve having both positive and negative lobes is the voltage. The non-symmetrical character of this curve is due to the drop in the resistance in series with the primaries of the transformers. The curve lying mainly below the axis represents the current flowing between the wire and tube. The part of this curve slightly above and slightly below the axis is of the same shape and order of magnitude as the charging current of the condenser formed by the wire and cylinder. This was determined by an oscillogram taken at a voltage slightly less than that necessary to form corona.

The voltage at which negative corona starts as shown in this oscillogram is approximately twice the voltages across the tube at the instant that the discharge ceases.

The rectification with corona in hydrogen is practically perfect as is shown by the oscillograms in Figs. 8 and 9. Fig. 10 gives the voltage and current with corona in air at 100 mm. pressure. It is of interest to compare Figs. 8, 9 and 10 with those given by Bennett for air at low pressures (Trans. A. I. E. E., Vol. XXXII, Part II, 1913, p. 1787.).

Digitized by Google

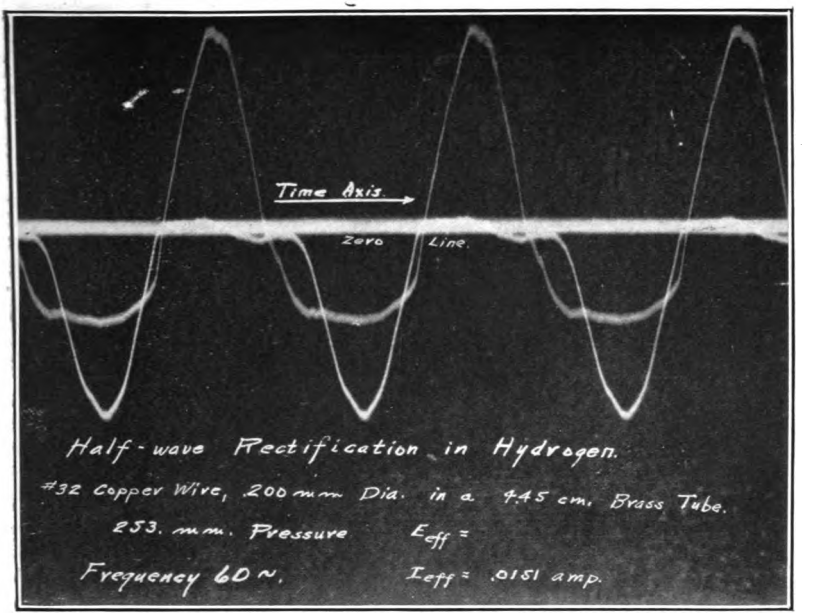
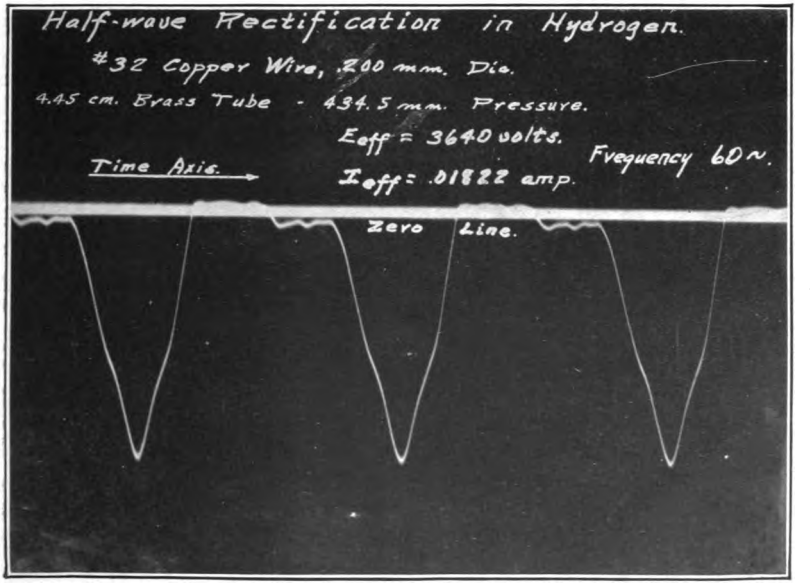

Time Axis.
Zero Line.
Half-wave Rectification in Hydrogen.
#32 Copper Wire, .200 mm Dia. in a 4.45 cm. Brass Tube.
253. mm. Pressure
Eeff =
Frequency 60 ~.
Ieff = .0151 amp.

FIG. 8


Half-wave Rectification in Hydrogen.
#32 Copper Wire, .200 mm. Dia.
4.45 cm. Brass Tube - 434.5 mm. Pressure.
Eeff = 3640 volts.
Frequency 60 ~.
Time Axis.
Ieff = .01822 amp.
Zero Line.

[DAVIS AND BREESE]

FIG. 9

Digitized by Google

Digitized by Google

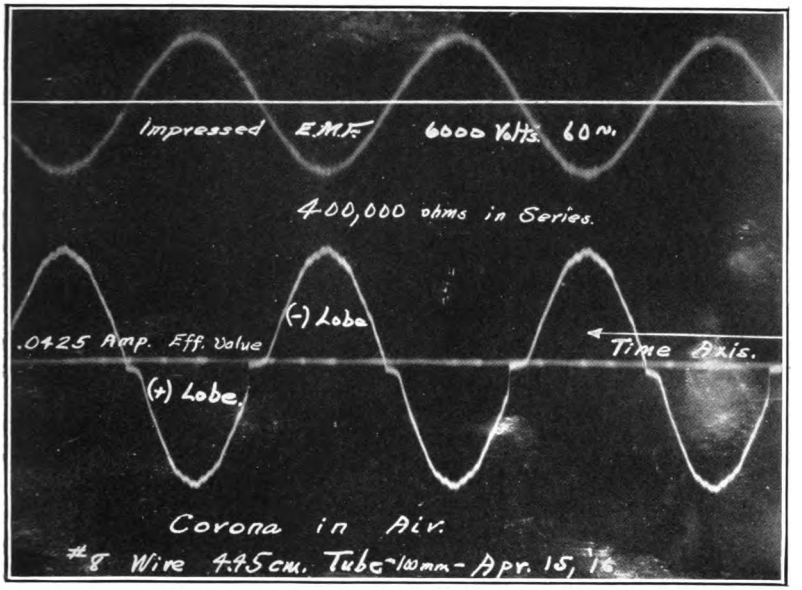
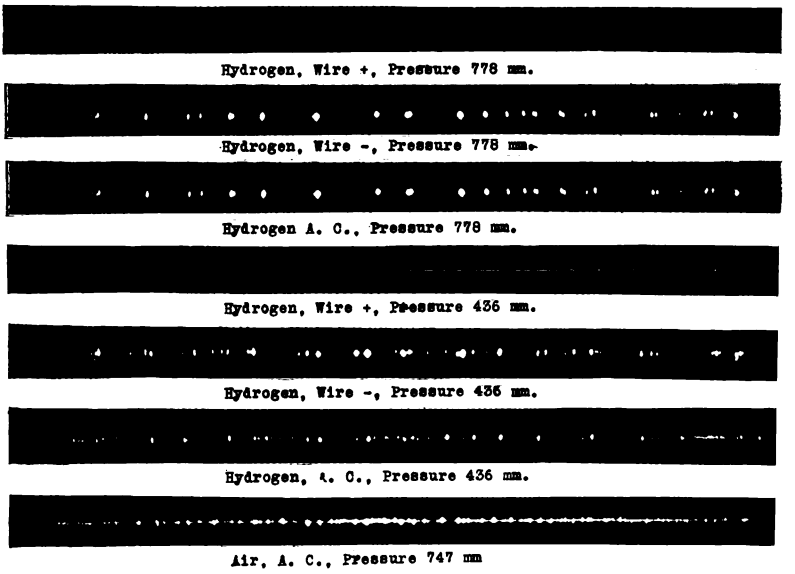


FIG. 10


Hydrogen, Wire +, Pressure 778 mm.
Hydrogen, Wire -, Pressure 778 mm.
Hydrogen A. C., Pressure 778 mm.
Hydrogen, Wire +, Pressure 436 mm.
Hydrogen, Wire -, Pressure 436 mm.
Hydrogen, A. C., Pressure 436 mm.
Air, A. C., Pressure 747 mm

[DAVISAND BREESE]

FIG. 11—CORONA IN 4.45-CM. BRASS TUBE WITH 0.200-MM. COPPERWIRE

Digitized by Google

Digitized by Google

The irregularities in the part of the curve near the zero line seem to be due to the capacity effect and are in no sense characteristic of the corona discharge.

The whole question of rectification is at present being made the subject of further investigation.

General Appearance

In general appearance the corona in hydrogen is similar to that in air, but upon critical examination it is seen that there are many points of difference. Some of these similarities and differences are shown in Fig. 11.

With the wire positive and sizes of wire smaller than No. 26 B. & S. (0.405 mm. diam.) the wire was surrounded by a thin luminous layer which was essentially uniform. This is shown in Fig. 11. As the size of the wire was increased this glow became more and more irregular. At first there were spots somewhat brighter than others. For a wire as large as No. 10 B. & S. (2.59 mm. diam.) the discharge took the form of a large number of brushes similar to the point discharge in air. These brushes were closely spaced along the length of the wire with a fairly uniform glow between them. It was impossible to obtain a satisfactory photograph of this. This discharge was blue in color. If the voltage was increased to a high value a brilliant red spark passed between the wire and tube. This was followed by a pale blue arc having incandescent blue spots at both ends.

The typical form of discharge with the wire negative is also shown in Fig. 11. It is seen that the discharge consisted of bright beads on the wire. As the potential was continuously increased, the first evidence of a breakdown of the gas was the appearance of an intermittent flickering glow. In every case the first noticeable current and visible corona occurred simultaneously. If bright spots were formed on the surface these increased in number and the current gradually increased until a stage was reached where the small bright spots collapsed into one brilliant bead. This change was accompanied by a rapid increase of current and a drop in the voltage across the tube. (See Fig. 6.) A further increase in voltage caused more small bright spots to form and also caused an increase in the brilliancy of the beads. The bright spots collapsed into another bead and in this manner the number of beads and the current increased as the generator voltage was made larger. If the generator

Digitized by Google

voltage was now decreased the behavior of the corona was somewhat different. Suppose that there were nine beads on the wire. These beads persisted and became less and less brilliant until they finally collapsed into one or two beads. Thus it is seen that with increasing voltage the beads appear one after another, while with decreasing voltage they will continue until several disappear at one time, thus concentrating the current in a smaller number of more brilliant beads.

With the wire negative there was no evidence of a uniform glow for any size of wire or any pressure covered in this investigation unless an arc was in series with the tube. This is not true with air.

Opposite to each bead for practically all pressures and all sizes of wire used in these experiments there were a number of bright spots on the tube. The number of spots varied from ten or twelve up to a hundred or more depending upon the current flowing from the bead. If there were only a few spots they would be bunched together, but when the current was large the spots formed a band with a width of approximately one centimeter completely surrounding the tube. These spots varied in color from pale yellow to milky blue, depending on the pressure, current and size of wire. With low pressures and large currents these spots appeared as brilliant green fans with yellow spots where they touched the tube. The effect was then truly beautiful. This green color may be due to the brass tube, and thus may not be characteristic of hydrogen. The presence of these spots seems to indicate an ionizing gradient at the surface of the tube.

With an alternating voltage impressed across the tube the corona may take the form shown in Fig. 11. In the illustration for 436 mm. this is essentially the same as the negative corona, since the conditions under which this picture was taken were such that there was perfect rectification and no positive corona was present. If any positive corona was present it would be made evident by a uniform glow between the negative beads. The corona in air with alternating voltage is also shown in Fig. 11. The difference is at once apparent. If the alternating voltage on the hydrogen filled tube is increased sufficiently positive corona will form and finally the positive arc will follow. The arcing during the half cycle when the wire is positive can be determined immediately, both by the fact that the red positive spark is easily visible shooting across the blue corona and negative

Digitized by Google

discharge, and also by the fact that the rectification is much less perfect.

The predominating color of the various discharges through hydrogen was blue, ranging from a light silver blue to sky blue. The one marked exception to this was the brilliant red of the disruptive discharge from a positive wire. This brilliant red spark was followed by a pale blue arc.

When a continuous voltage was impressed on the tube and a short arc (1mm. or less) was introduced into the circuit the following changes in the character of the discharge were observed.

With a No. 26 B. & S. gage (0.405 mm. diam.) wire in the tube and the wire positive, the introduction of a short arc caused the uniform glow to break up into straight blue streamers extending from the wire to the tube with brilliant light blue spots at each end. This discharge resembled a radial shower of blue light. Lengthening the arc caused the streamers to disappear and the entire tube was filled with a blue glow. With a No. 36 B. & S. gage (0.121 mm. diam.) wire, the radial streamers did not appear when the arc was introduced in the circuit, but the tube was filled with a blue glow.

With the wire negative the introduction of an arc in series with the tube caused very little change in the appearance of the corona at the surface of the wire, but caused a disappearance of the bright spots on the surface of the tube.

With the wire negative and hydrogen in the space between the wire and the cylinder an increase in the gas pressure as great as 3 cm. of mercury has been observed on closing the circuit. This pressure increase was due to ionization of the gas and not to increased temperature as it immediately disappeared when the current was shut off.

Conclusions

1. The critical intensity for corona in hydrogen follows Peek's law fairly closely as far as changes due to variations in the gas pressure are concerned.

2. The variation of the critical intensity with the radius of the wire is not as yet conclusively proved either to follow or not to follow Peek's law but the general character of the results so far obtained seem to indicate that the law may hold.

3. Hydrogen is different from air in that corona is maintained at voltages considerably lower than the critical voltage while this has not been found to be the case with air.

Digitized by Google

4. The characteristic curves with the wire positive in hydrogen differ from those with air in that the voltage necessary to maintain a given current depends on whether that value of current has been approached by increasing or decreasing the machine voltage.

5. The characteristic for the wire negative in hydrogen is entirely different from the characteristic obtained with a negative wire in air.

6. Complete rectification for alternating current is obtained between concentric cylinders when the intervening space is filled with hydrogen and an alternating potential difference sufficiently high to produce negative corona is impressed between the cylinders.

7. This rectification continues after the negative arc has been established, under the proper conditions of pressure, size of wire and size of tube. Direct currents as high as 0.12 ampere have been obtained with alternating voltages of approximately 8000 volts.

The investigations outlined in this paper were carried out in the Laboratory of Physics at the University of Illinois under the direction of Dr. Jacob Kunz, Associate Professor of Physics. To him, to Professor E. B. Paine of the Department of Electrical Engineering and to Professor A. P. Carman of the Department of Physics the authors wish to acknowledge their indebtedness for suggestions and aid which made this work possible.

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 15, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

THE ELECTRIC STRENGTH OF AIR.—VII

BY J. B. WHITEHEAD AND W. S. BROWN

ABSTRACT OF PAPER

In view of the variation among the values obtained by different observers, this paper aims to make a careful determination of corona-forming voltages for alternating and for positive and negative continuous voltages in the same apparatus and under the same conditions.

Within the range of wire diameters used, corona appears at a lower value when the wire is positive than when it is negative, although the two curves converge for increasing diameters. The maximum excess of negative over positive, as observed, was 6.3 per cent.

The values with alternating voltage coincide with those of negative continuous voltage. Positive continuous voltage therefore forms corona at the lowest value.

The observations on the negative corona give values higher than any heretofore obtained.

Other experiments are described, giving qualitative indications of the correctness of Townsend's theory of ionization by collision.

THE voltage at which corona appears on a round wire in air depends on the diameter of the wire, the potential gradient at the surface and the density of the air. The relation as based on the results of these papers and those of Peek[1] is of the form,

$$E = A\,\delta + B\sqrt{\frac{\delta}{d}} \qquad (1)$$

in which E is the potential gradient at the surface of the wire of radius r or diameter d, δ is the so-called "density factor", its value being unity at a pressure of 76 cm. and a temperature of 25 deg. cent., and A and B are constants. In the experiments on which formula (1) is based alternating voltages were used, and it was shown that the maximum value of voltage or gradient determines the appearance of corona.

If the value of E as obtained from the empirical formulas of Whitehead[2] and Peek and from the results of some of the other investigators of the alternating-current corona be plotted as a function of the radius of the wire, we find that the value of E for

Manuscript of this paper was received September 15, 1916.

Digitized by Google

any one wire shows noticeable discrepancies, *i.e.*, the constants A and B have different values. The differences in the observed values are probably due to the difficulty in measuring the ratio of maximum to effective values of the high voltage, to the unequal surface condition of the wires and to failure to properly correct for atmospheric conditions. The observations of Whitehead gave $A = 32$ and $B = 13.4$. The work of Peek[1], somewhat later, showed a similar relation between E and d, giving $A = 29.8$ and $B = 12.7$. These values in his subsequent papers have been brought up to 31.0 and 13.5 respectively, which are in close agreement with the result of Whitehead.

The most important work on the direct-current corona has been done by Watson[3], Shaffers[4], and Farwell[5]. Watson made observations with wires ranging from 0.70 mm. to 12.76 mm. in diameter, using as a source of power an influence machine of special design. For the case of a wire and cylinder he found that the polarity of the wire had a marked influence on the appearance of corona and on the value of the critical intensity. Schaffers, using wires from 0.0006 to 0.70 cm. in diameter in tubes of various sizes, found that for the larger wires the positive corona appeared at a lower voltage than the negative, while for the smaller sizes the reverse was true. The curves of critical intensity crossed at a point corresponding to a wire 0.01 cm. in radius.

Farwell, using a series of 500-volt generators as a source of high potential, investigated the influence of the polarity of the wire, of temperature, pressure and humidity on the corona, forming voltages on copper wires ranging from 0.009 to 0.258 cm. in diameter in a tube 4.45 cm. in diameter. For a given size wire, he found that corona appeared at a much lower voltage when the wire was positive. His observations can be represented by formula (**1**) and the value of the constants as given in his A. I. E. E. paper are for the positive wire, $A = 31.6$ $B = 8.47$, for the negative wire, $A = 38.0$, $B = 8.06$. Here again, as in the alternating-current case, the results of different investigators show considerable divergence.

It was in view of these differences among the values of the constants of formula (**1**) as determined by different observers that the present investigation was undertaken. The different conditions under which the several investigators worked should account in a large measure for the different values obtained for both alternating and continuous voltage. The aim of the present

Digitized by Google

experiments has been to compare alternating and continuous values of corona voltage under identical conditions and under the best possible conditions for accuracy.

Some later experiments outlined in Section V had as their purpose the testing of some of the assumptions of the present day theories as to the start and ultimate nature of corona.

Since the experiments of this paper were completed Peek[10] has published results of a comparison of alternating and continuous corona voltages. He finds that they are identical and independent of the polarity of the wire in the case of continuous voltage. The results described in this paper are noticeably at variance with those of Peek.

II. Description of Apparatus

For Alternating Voltages. The diagram of connections for the production of and measurements on the alternating-current corona is given in Fig. 1. The motor-generator G supplies the

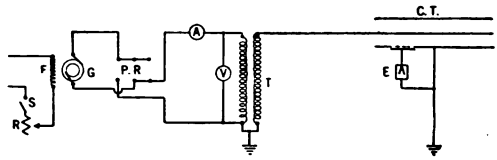


FIG. 1

low-tension winding of the transformer T through a potential regulator, $P\ R$. One terminal of the high-tension winding is connected to the low-tension winding and to ground and the other to the corona wire. $C\ T$ is the corona tube and E, an electroscope, both described in detail in a subsequent paragraph.

The motor-generator set consisted of two 5-kw., 1200-rev. per min., 120-volt alternating-current generators, one 60 and the other 20 cycles driven by a 7.5-h.p., 120-volt direct-current, shunt-wound motor. The use of a storage battery of large capacity as a source of energy for driving the motor and for exciting the two alternators made it possible to obtain a very constant voltage. Throughout the experiments only the 60-cycle unit was used. The armature was surface wound and the wave smooth.

The transformer used was rated at 3000 watts, 60 cycles, 100-25,000 volts. The low-tension winding was in two 50-volt sections, the high-tension in four 6250-volt sections. The ratio

Digitized by Google

of turns of the transformer as furnished by the manufacturer was 1-250.18 and this ratio was used to determine the secondary voltage. The primary voltage was read on a standardized Weston dynamometer voltmeter V (Fig. 1) and was controlled by the potential regulator P R and a variable resistance R in the generator field F. The influence of the varying I R drop in the primary winding was practically negligible in its effect on the ratio of transformation owing to the small values of the magnetizing and load currents.

The corona apparatus consisted of a wire stretched co-axially in a metal tube. The wire was clamped at each end in a device which permitted stretching and centering. The tube was mounted on an insulated stand which also supported a very sensitive electroscope. Small holes were drilled in a section of the tube and a disk of the same curvature as the tube was connected to one terminal of the electroscope and placed as close to the tube as possible without actual contact. The disk, the con-

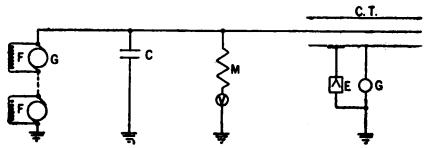


FIG. 2—CONNECTIONS FOR EXPERIMENTS WITH 15,000-VOLT DIRECT CURRENT GENERATOR

nections to the electroscope and the electroscope proper were protected by grounded metal shields. The electroscope was charged to a potential of 440 volts from the lighting mains through lamps and condensers by parallel-series connection. The insulated stand was grounded for the alternating-current observations thus grounding the other terminal of the electroscope. The ionization accompanying the very first appearance of co ona causes the electroscope to discharge rapidly, which thus served as detector of corona. Fig. 4 is an illustration of the tube as used in some later experiments.

For Continuous Voltages. Two sources of high continuous voltage were available, a high-voltage generator and a kenotron or hot-cathode rectifier. The diagram of connections in the use of the former is shown in Fig. 2. G the generator, supplies the high potential through parallel condensers C to the corona wire. V M and G' are a voltmeter, multiplier and galvanometer respectively.

Digitized by Google

The generator of special design consisted of eight units mounted on an insulating bed. Each armature is provided with two windings and commutators and rated as follows: Amperes 0.1; speed, 2700 rev per min.; volts per commutator, 937.5; shunt wound. The available potential was, therefore, 15,000 volts, when the machine was run at normal speed with all the units in series.

The connection of a large number of low-voltage generators in series as a method of obtaining high values of continuous potential has been often used. In the present case to avoid insulation troubles, self-excited, shunt-wound generators were used with individual rheostats mounted on each frame and special precautions were taken in the design of the insulation. The generators were driven by a 5-h.p., 220-volt direct-current, shunt-wound motor through an insulating belt and insulated couplings. Voltage control was obtained in two ways. Adjustable carbon rod resistances connected in series with the generator fields and carefully insulated from the frame were mounted on the top of each machine and a movable insulated gearing provided uniform variation of all the rheostats. For fine adjustment a rheostat was inserted in the driving motor field which gave voltage control by varying the motor speed. An illustration of the unit is given in Fig. 5.

The Moscicki condensers, whose function will be explained later, were rated at 20,000 volts, effective value. They are of the Leyden jar type, the dielectric being of glass; and to prevent corona from forming on the edge of the plates, the condensers were filled with oil. Two condensers were used, consisting of eight units of 0.002 microfarad each.

The voltmeter used was a Weston intrument of the permanent magnet type, with two scales (0-150 and 0-750 volts). It was carefully compared throughout its entire range with a Weston laboratory standard instrument and found correct within the limit of observation error, *i.e.*, 0.1 per cent. The resistance of the high scale winding was 82,790 ohms. As it was desired to measure potentials up to 35,000 volts, a multiplier of 4.5 megohms was necessary. Shunting the instrument by an approximately equal resistance reduced this amount by one half although it introduced the disadvantage of doubling the amount of power required. For example, at 15,000 volts this demand is 0.0065 ampere and is great enough to impose a serious limitation on some of the later experiments, using the kenotron. A number

Digitized by Google

of multipliers of the regular type supplied by the voltmeter manufacturers for increasing the range of their laboratory voltmeters were available. Their total resistance, however, was only 707,630 ohms. To obtain the remainder, six units were made up in this laboratory according to specifications of the Bureau of Standards. Each unit consisted of forty mica cards wound with manganin wire. The resistance of each card was approximately 6000 ohms. They were mounted on horizontal glass rods, which in turn were supported by hard rubber uprights, and the whole mounted on a hardwood base. The current capacity was 0.022 amperes. The resistance of each unit was measured with a standard bridge and also by placing it in series with a standard Weston voltmeter of known resistance across mains of known potential.

The diagram of connections for the second method using a kenotron is shown in Fig. 3. G the high-frequency generator

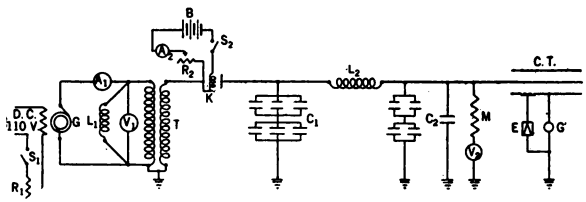


FIG. 3—CONNECTIONS FOR EXPERIMENTS WITH THE KENOTRON

supplies, through the grounded transformer T the kenotron K with high voltage. The condensers C_1 and C_2 and the inductance L_2 are introduced to smooth out the voltage which is rectified in pulsating form by the kenotron. M and V_2 are the multiplier and voltmeter, as used in the first method and $C\ T$ is the corona tube, with the electroscope E and the galvanometer G' as before. L_1 is an inductance, V_1 a hot wire voltmeter, and A_1 a hot band ammeter. Voltage control was obtained by varying the field circuit of the generator by means of the resistance R_1.

The high-frequency generator was a direct-driven unit consisting of a generator with a double field structure, one of 48 poles, the other of 240, and a 3-h.p., 240-volt direct-current, shunt-wound motor. The armature of the alternator was stationary and provided with a distributed winding. The rated full speed was 1500 rev. per min. at which one generator gave 600 cycles and the other 3000. The generators were rated at 4.4 amperes and 110 volts.

Digitized by Google

Speed or frequency control was obtained by armature and field resistance in the motor circuit, the use of the former being practically limited to starting. The driving motor and the generator field were both supplied from a storage battery which made conditions very favorable for steadiness in readings.

The kenotron used in the present investigation was designed for a maximum voltage of 40,000. It consisted of a highly evacuated glass bulb containing a cylindrical anode along whose axis was stretched a 10-mil tungsten filament, which acted as the hot cathode. The cylindrical anode was of small diameter in order to bring the anode and cathode very close together to reduce the space charge effect and thereby increase the current carrying capacity of the rectifier. One terminal was of the ordinary incandescent lamp type and served to supply energy to the cathode, acting at the same time as one terminal for the high voltage. The other end of the tube was sealed off with a metal cap and ring, which served as the other high-voltage-terminal. The theory and performance of the kenotron have been completely described by Dushman[6] and others.

For heating the tungsten filament, a 12-volt storage battery B Fig. 3 was used. A resistance R_2, a 15-ampere ammeter A_2 and a knife switch S_2 were connected in series with the battery to provide control of the filament current and indirectly the electron emission. Table I gives the electron emission and the voltage drop in the kenotron for various filament currents. A filament current of 6.1 amperes was used throughout this work.

TABLE I—CHARACTERISTICS OF THE KENOTRON

Filament current	Electron emission	Minimum voltage drop
5.0	9.5	...
5.2	16.0	86
5.4	27.0	122
5.6	40.0	158
5.8	57.0	200
6.0	82.0	250
6.1	100.0	280

The capacity C_1 (Fig. 3), was made up of six units connected two in series, three in parallel. Each unit was insulated for 10,000 volts and had a capacity of 0.01 microfarad. The con-

Digitized by Google

denser plates were immersed in oil. Spark gaps set for 10,000 volts were placed across the terminals of each unit to prevent breakdown of the insulation resulting from possible unequal distribution of potential. The capacity C_2 was made up of four similar units connected two in series, two in parallel together with the Moscicki condensers used in connection with the first method. The inductance L_1, consisted of two air coils of 360 turns of No. 10 B. & S. wire. The coils were in parallel but magnetically separated from each other. At 600 cycles they had an impedance of 9 ohms each. The high-tension winding of a 5 kw., 6600/110-volt, 60-cycle power transformer served for L_2. The function of these inductances is explained in connection with the experiments.

III. Preliminary Experiments

The approximate sizes of wire on which corona would appear for both alternating and continuous voltages with tubes of a given diameter were calculated from the results of foregoing researches. Two tubes were used, with inside diameters of 6.109 and 4.855 cm., respectively. Six sizes of wire were used, with diameters of 0.074, 0.090, 0.125, 0.166 and 0.231 cm. All were of brass except the largest, which was of steel. The wires were always carefully polished with crocus cloth and chamois before introducing them into the tube.

The first tests made were with the high-voltage generator as a source of potential. A number of runs were made on the same tube and wire and the voltage at which corona appeared, as determined by visual methods and temperature and atmospheric pressure, were recorded. An interesting source of error was developed at this point. It was found that successive runs under the same conditions gave values of corona voltage differing by several per cent. The trouble was traced by means of oscillograms to periodic fluctuations in the continuous voltage (see Fig. 6) of high frequencies which could not be associated with any feature of the rotating element.

In an effort to smooth out the inequalities of voltage, two Moscicki condensers (0.004 microfarad) were connected in parallel with the generator. The oscillograms shown in Fig. 6 show that the voltage fluctuation was increased under these conditions. Sixteen Moscicki units (0.032 microfarad) were then used and the oscillogram, Fig. 7, shows that the voltage was then practically constant. The frequency of the oscilla-

Digitized by Google

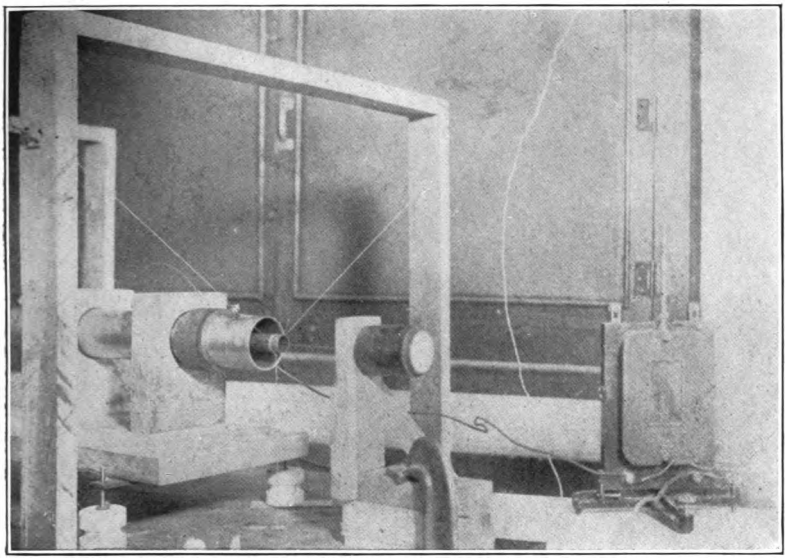
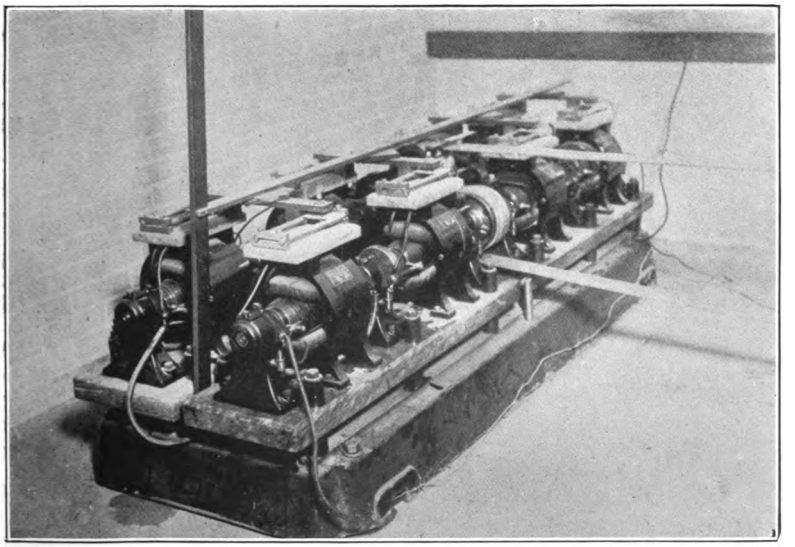


FIG. 4—CORONA TUBE



[WHITEHEAD AND BROWN]

FIG. 5—HIGH-VOLTAGE GENERATOR

Digitized by Google

Digitized by Google

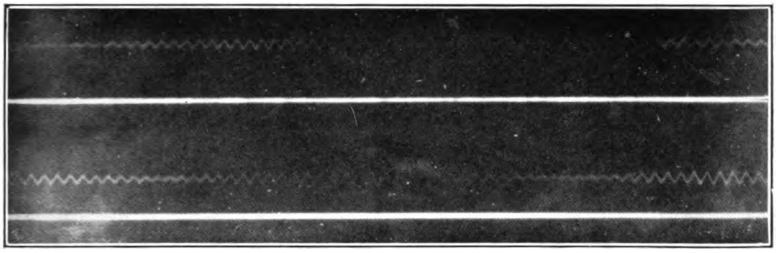


FIG. 6

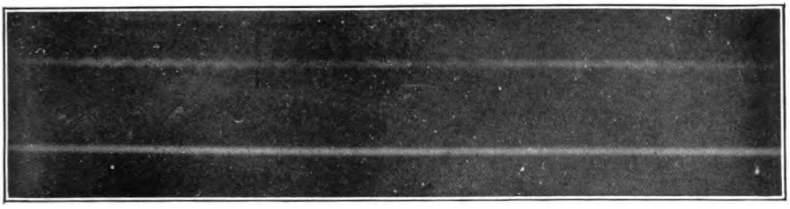


FIG. 7

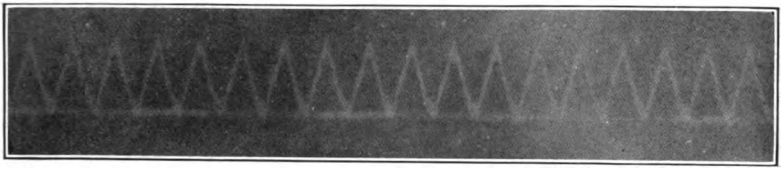


FIG. 9

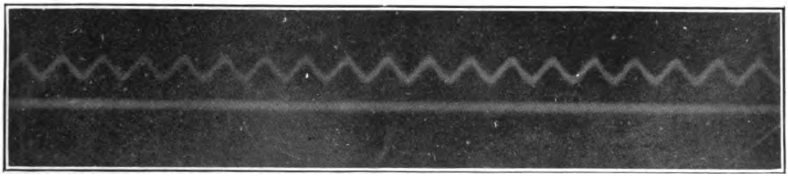
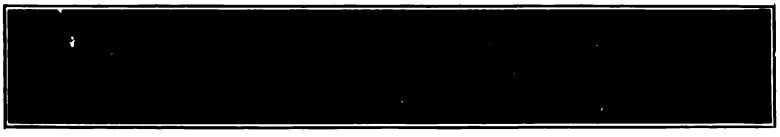


FIG. 10



[WHITEHEAD AND BROWN]

FIG. 11

Digitized by Google

Digitized by Google

tions, when the two units were used, was obtained by superimposing a wave of known frequency, not shown in Figs. 6 and 7. The frequencies as measured in this way are for the fundamental, 359.5 cycles per second, and for the superposed, 12.3 cycles per second. An effort was made to connect these frequencies with periodic recurrencies due to the speed of the motor, the generators, the belt, the number of commutator segments, etc., but without success. The fluctuation disappeared with increased capacity in parallel and is probably due to a resonance condition between the inductance of the armatures and the capacity of the circuit. The slow superimposed fluctuation could not be definitely traced. Further investigation of this interesting phenomenon had to be postponed.

A determination of E as a function of the capacity in parallel with the generator showed that above 0.016 microfarad the value of E was constant. The results are given in Table II and are plotted in the form of a curve in Fig. 8. A capacity of 0.032 microfarad was used, twice as much as actually required.

TABLE II—APPARENT LOWERING OF THE CRITICAL SURFACE INTENSITY DUE TO RESONANCE IN THE GENERATOR CIRCUIT

No. of units	Capacity m.f.	Voltmeter reading	Critical surface intensity E
1	0.002	620.0	68.6
2	0.004	555.0	61.4
3	0.006	622.5	68.9
4	0.006	647.5	71.7
5	0.010	652.5	72.2
6	0.012	662.5	73.3
7	0.014	666.0	73.7
8	0.016	665.0	73.7
9	0.018	665.0	73.7
10	0.020	665.0	73.7
11	0.022	665.0	73.7
12	0.024	665.0	73.7
13	0.026	665.0	73.7
14	0.028	665.0	73.7
15	0.030	665.0	73.7
16	0.032	665.0	73.7

It must be noted that the percentage variation in voltage as shown by the oscillogram (Fig. 9) is much greater than that actually obtaining under test conditions, as the oscillograph requires a current nearly 25 times as great as that taken by the voltmeter and corona tube and the fluctuation varies directly

Digitized by Google

with the current taken from the condensers. Under test conditions therefore—voltmeter and tube connected—the voltage variation is only a very small fraction of one per cent.

The maximum voltage obtainable from the high-voltage generator was 15,000 volts so the kenotron was used for higher values. It was soon found that the transformer used imposed a serious limitation on the value of the continuous voltage obtainable by this means. At 600 cycles the high-tension windings of the transformer took a primary charging current of 20 to 25 amperes and as the full load current of the 600-cycle generator was only 4.4 amperes, the speed and consequently the frequency rapidly dropped on connecting the transformer. Although the internal reactance of the generator was considerable, the capacity of the high-tension windings of the transformer was more than sufficient to overbalance it. Additional reactance connected

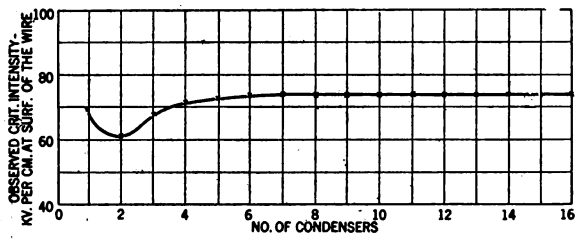


FIG. 8—APPARENT LOWERING OF CRITICAL SURFACE INTENSITY DUE TO RESONANCE IN THE GENERATOR CIRCUIT

accross the primary of the transformer was the obvious way of reducing this current. A number of air coils of low resistance were tried and after a number of trials the two coils as described in an earlier paragraph were selected, as they reduced the charging current to about five amperes and gave a maximum value of continuous voltage of about 26,500 volts.

The next step in the development of the kenotron method was to introduce parallel capacity in the direct-current side of the kenotron to smooth out the voltage by supplying energy to the load during the part of each cycle when the kenotron delivers no current. When operated alone *i.e.*, without condensers the rectifiers gave a continuous voltage which fluctuated between zero and a maximum with the frequency of the impressed e.m.f., 600 cycles. Four 10,000-volt condensers in series (0.0025 microfarad were connected between the direct-current side of the kenotron

Digitized by Google

and ground. The oscillogram, Fig. 10, shows the character of the continuous current voltage with the above capacity. Nine condensers, connected three in parallel, three in series, (0.01 microfarad) were next tried. The oscillogram, Fig. 11, shows the decided improvement. The attempt to produce further improvement in the voltage by this means was abandoned as it was evident that a far larger amount of capacity than was available would be required to obtain a voltage varying less than one per cent.

As the impedance of the load (the voltmeter and corona tube) was high, the current which flowed was very small. Under these conditions a moderate amount of series inductance (50 or 100 henrys) in conjunction with capacity offered a probable means of further improvement if connected in the manner shown in Fig. 3, where the capacity is divided into two portions. The voltage fluctuation at the terminals of C_1 is an irregular shaped wave which consists of a fundamental with a frequency of 600 cycles per second and a number of higher harmonics. The inductance L_2 and the capacity C_2 offer a definite value of impedance to each of these higher frequencies. The higher the frequency the greater the impedance offered by the inductance, L_2 or in other words the voltage wave is smoothed out by removing the higher harmonics. The current drawn by the condenser, C_2 over the inductance L_2 stores up electromagnetic energy in the latter. When the voltage of the condenser starts to fall, due to the current drawn from it by the load, the energy stored up in the inductance is delivered to the circuit and tends to maintain the voltage at the terminals of C_2 constant.

A number of inductances were tried in the position L_2 and the sound in a telephone used as a measure of the degree of voltage fluctuation. The intensity of sound in the telephone is proportional to the amplitude of the voltage fluctuation. The minimum sound in the telephone was obtained from one half of the high-tension winding of a 5-kw., 6600/110-volt power transformer. This final arrangement was used throughout the tests.

It is possible to calculate the voltage fluctuation under test conditions, if it is assumed that is directly proportional to the current. Referring to Fig. 3, the values were as follows, when the oscillograph was in circuit:

Digitized by Google

$$C_1 = \frac{3\,(0.01)}{2} = 0.015 \text{ microfarad}$$

$$C_2 = \frac{2\,(0.01)}{2} + 0.032 = 0.042 \text{ microfarad}$$

$$C = C_1 + C_2 = 0.015 + 0.042 = 0.057 \text{ microfarad}$$

$$= 5.7 \times 10^{-8} \text{ farads}$$

V = direct-current voltage = 4700

δV = voltage fluctuation = 13.8 per cent = 650 volts.
(By measurement on the oscillogram)

i_1 = oscillograph current = 0.024 ampere
(By measurement)

i_2 = voltmeter current = 0.001 ampere
(By calculation)

i = total current flowing when oscillograph is connected.

$$= i_1 + i_2 = 0.025 \text{ ampere}$$

$$\omega = 2\pi \times \text{frequency} = 2\pi \times 600 = 1200\pi$$

Hull[7] has shown that the voltage fluctuation (δV) at the terminals of C_2 may be expressed by the simple relation

$$V = \frac{8\,i\,\pi}{L_2\,\omega^3}\left(C + \frac{1}{L_2\,\omega^2}\right)^2 \qquad (2)$$

where i, ω, and C are as given above and L_2 is the magnitude of the series inductance in henrys. If we assume L_2 constant, (*i.e.*, independent of the amount of current due to the low flux density in the iron of the transformer which was used as L_2), we can write

$$\delta V = K i \qquad (3)$$

Let δV_a = voltage fluctuation when current i is flowing.
δV_b = voltage fluctuation when current i_2 is flowing
Then, $\delta V_a = K i$; and, $\delta V_b = K i_2$. (4) and (5)

Digitized by Google

Dividing (4) by (5) and transposing,

$$\delta V_b = \frac{i_2}{i} \times V_a \qquad (6)$$

$$= \left(\frac{0.001}{0.025} \times 13.8\right) \text{per cent} = 0.5 \text{ per cent}$$

= percentage voltage fluctuation under test conditions, (*i.e.*, voltmeter and corona tube.)

A comparison of the different methods of detecting corona was then made. In the case of the alternating-current corona the

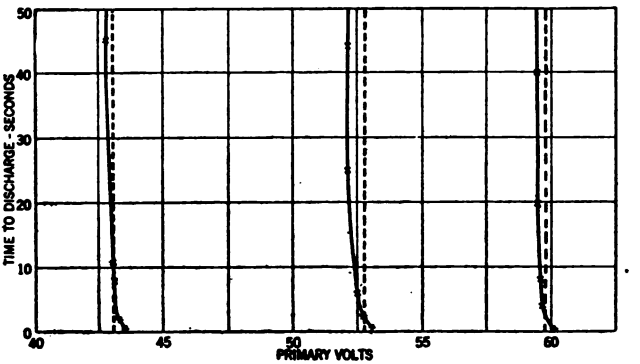


FIG. 13—VISUAL CORONA AND ELECTROSCOPE DISCHARGE
- - - Visual corona
—— Electroscope discharge
Diameter tube = 6.109 cm.
Diameter wires = 0.107—0.166—0.231 cm.

visual and electroscope methods were compared. The curves (Fig. 13) show how closely the two methods agree, when the bend in the electroscope curve is taken as the point at which corona begins. In the case of the direct-current corona an additional method was available, *i.e.*, a galvanometer connected between the tube and ground as used by Farwell and Mackenzie[8]. A ballistic galvanometer with a sensitivity of 10^{-6} amperes per mm. scale division when the scale was placed one meter from the mirror, was used. Below corona voltage if the wire was clean, the galvanometer stood practically on zero. With the appearance of corona, the galvanometer took a large deflection (5 to 10 cm.) and any further increase in voltage threw the light spot off the scale.

Digitized by Google

The condition of the surface of the wire when fairly clean had but little effect on the value of the critical surface intensity in the case of the wire at positive or alternating-current potentials, but with the wire negative the slightest surface imperfection or particle of dust caused a lowering of the value of E. The observations on negative corona were extremely difficult on this account. On raising the voltage the slightest amount above that necessary to form corona, the blue glow changed to a purple point discharge and on lowering the voltage, corona held on to a value of voltage far below that required to start corona. The wire had to be removed and carefully polished again before another observation could be made. With precautions against the above increase of voltage beyond corona value it was possible to repeat the observations on the negative corona as often as desired.

Final Methods of Taking Observations. The wire was carefully polished, placed in the tube, accurately centered and connected to the voltage supply. In the alternating-current case the voltage was slowly raised by increasing the generator field current until the electroscope began to discharge. Readings were taken of the rate of leak of the electroscope corresponding to each increment of the voltage, until the rate of discharge became practically infinite. The field current was then decreased until the leak of the electroscope ceased and then increased again until visual corona appeared. The voltage was read at this instant on the primary voltmeter and recorded as primary volts. The temperature and pressure were also recorded. The peak factor of alternating voltage waves was determined by means of oscillograms. A large number were taken and from these the values of 1.46 at 40 volts, 1.46 at 50 volts and 1.46 at 60 volts were determined by measurement. In order to give an idea of the conditions of accuracy in making these measurements, the figures in Table III are given for one half of the wave of the oscillogram corresponding to 60 volts. The curve was carefully traced on co-ordinate paper and 26 ordinates, 1/20 of an inch (1.27 mm.) apart were read off; the height of each ordinate could be read to 1/50 of an inch (0.508 mm.) The maximum ordinate was 1.43 inches (37.08 mm.) high and the r.m.s of all the ordinates was 0.977, which gives a ratio of maximum to effective of 1.464. Similar measurements on the other oscillograms gave the values as stated above. The average of these three (1.46) was taken as the ratio of maximum to effective value over the range 40-60 primary volts.

Digitized by Google

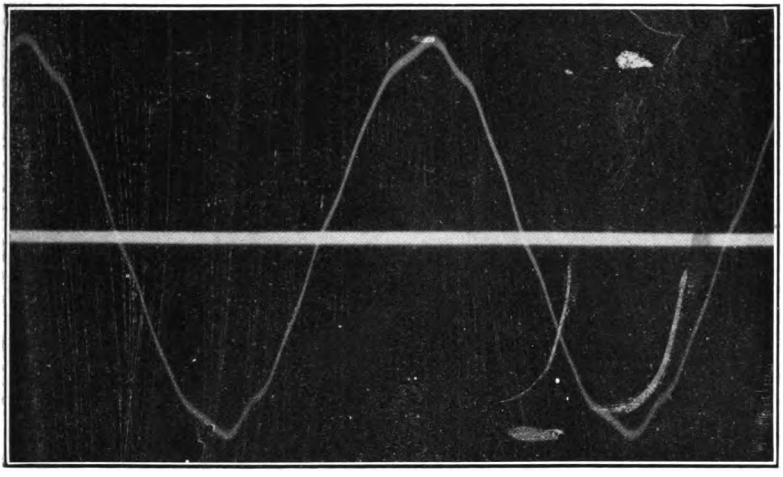
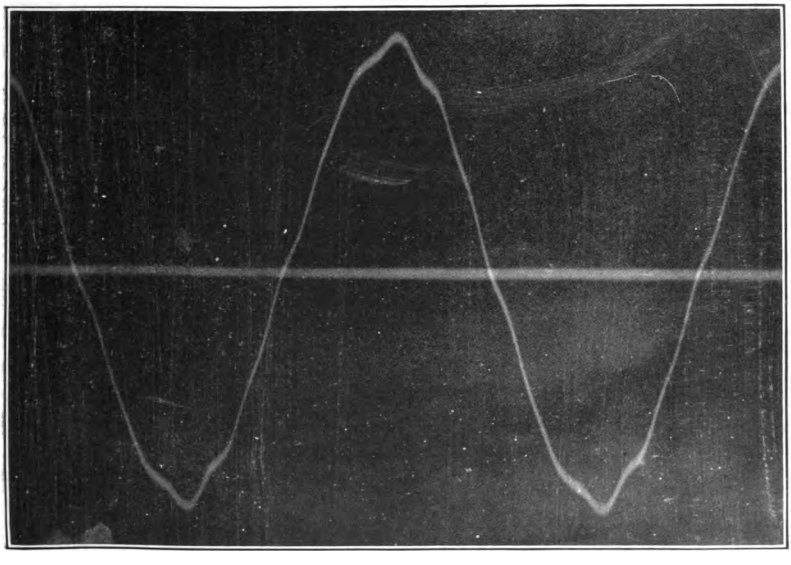


FIG. 14—AT 40 VOLTS



[WHITEHEAD AND BROWN]

FIG. 15—AT 60 VOLTS

Digitized by Google

Digitized by Google

TABLE III—OSCILLOGRAM OF THE VOLTAGE ACROSS THE LOW-TENSION TERMINALS OF THE TRANSFORMERS AT 60 VOLTS

Ordinate No.	Length	(Length)
1	0	0
2	2.5	6.25
3	5.0	25.00
4	7.0	49.00
5	11.5	132.25
6	15.3	234.09
7	17.8	316.84
8	20.3	412.09
9	22.3	497.29
10	24.2	585.64
11	25.0	625.00
12	26.0	676.00
13	27.0	729.00
14	28.0	784.00
15	28.6	817.96
16	27.0	729.00
17	25.2	635.04
18	23.5	552.25
19	22.7	515.29
20	21.0	441.00
21	17.8	316.84
22	15.0	225.00
23	12.0	144.00
24	8.8	77.44
25	5.2	27.04
26	0.0	0.00

The oscillograms taken at 40 and 60 volts respectively are given in Fig. 14 and 15.

In the direct-current experiments the procedure was much the same, the high-tension voltage however being read directly on the voltmeter in series with the multiplier, no peak factor determination being necessary. In the case of the negative corona the electroscope curve could not be obtained due to the disadvantage of raising the voltage above corona as noted above and finally, the galvanometer method of detecting the corona was used.

Accuracy of Observations. The accuracy of observation in the case of the alternating-current corona was limited only by the accuracy of reading the voltmeter, as the observations could be repeated again and again from day to day when correction was made for temperature and pressure, and the other factors entering into the determination of the value of E could be determined to a small fraction of 1 per cent. The voltmeter could be read to 1/5 of a division at 60 volts or about 1/3 per cent. It is

Digitized by Google

recognized, however, that the accuracy also depended upon the measurements of peak factor on the oscillograms. The method of measuring these has already been outlined and as the value of the peak factor varied only 0.07 per cent over the range of voltage used, it is felt that the measurement of voltage is the limiting factor, as stated above. The accuracy in the continuous current case was also limited by the voltmeter reading and was about 1/3 per cent also.

IV. Final Experiments

Relation Between Critical Surface Intensity and Diameter of the Wire for Alternating Voltage. In Table IV are given the results of observations on six sizes of wire in a tube 6.109 cm. in diameter. The first column gives the wire diameter in centimeters, the second column the "density factor" δ, as obtained from Peek's relation

$$\delta = \frac{3.92\,\rho}{273 + t} \tag{7}$$

and the third column the primary volts. V the critical voltage (maximum) is obtained by multiplying the primary voltage by the ratio of transformation and the peak factor. The relation

$$E = \frac{V}{a \log_e b/a} \tag{8}$$

was used in calculating the critical surface intensity E.

Relation Between Critical Surface Intensity and Diameter of the Wire for Positive and Negative Continuous Voltage. In Table V are given the results of observations on the same wires for positive corona and in Table VI for negative corona. The first column is again the wire diameter, the second column the density factor calculated from the observed temperature and pressure and the third column the voltmeter reading. The critical voltage V is obtained by multiplying the voltmeter reading by the multiplying factor. The last column is obtained as before.

The small number of observations on the negative corona is due to the great difficulty experienced in obtaining them as mentioned before. As many as ten trials with their attendant polishing, centering, etc., were often required to obtain a stable corona. The galvanometer in the grounded circuit proved a great help as the galvanometer only remained on zero up to

Digitized by Google

corona forming voltage when the wire was absolutely clean and if at no time during the run the voltage had been raised above that required to form corona on the given wire.

Determination of the Constants A and B of Formula (1). As stated in the introduction the formula connecting E (the critical surface intensity) with the diameter of the wire is of the form

$$E = A\,\delta + B\sqrt{\frac{\delta}{d}} \qquad (1)$$

TABLE IV—ALTERNATING CURRENT

Diam. wire cms.	Density factor δ	Primary volts	Crit. voltage (maximum) V	Crit. surface intensity E (kv.)
0.074	1.005	35.8	13,120	80.6
	1.005	35.8	13,120	80.6
	1.005	35.8	13,120	80.6
0.090	1.005	39.65	14,530	77.1
	1.005	39.65	14,530	77.1
	1.005	39.65	14,530	77.1
0.107	1.005	42.85	15,700	72.6
	1.005	43.05	15,780	73.0
	1.005	43.20	15,830	73.2
0.125	1.005	45.6	16,700	68.8
	1.005	45.65	16,720	68.9
	1.005	45.7	16,750	69.0
0.166	1.005	53.5	19,610	65.6
	1.005	53.5	19,610	65.6
	1.005	53.5	19,610	65.6
0.231	1.005	61.4	22,500	59.6
	1.005	61.4	22,500	59.6
	1.005	61.4	22,500	59.6
0.231	1.000	64.2	23,520	59.7
	1.000	64.2	23,520	59.7
	1.000	64.2	23,520	59.7

where, E = critical surface intensity in kilovolts per centimeter.

δ = Density factor.

A and B = Constants.

To determine these constants from the observed results the method of least squares was used. The calculation as applied to the positive corona is given in full in Table VII. Attention is

Digitized by Google

TABLE V—POSITIVE CORONA

Diam. wire cms.	Density factor δ	D-C. volts	Mul. fac.	Critical voltage (V)	Crit. surf. intensity (E)
0.074	1.02	228.0	52.16	11,897	77.0
	1.02	227.5	52.18	11,871	76.9
	1.02	228.0	52.18	11,897	77.0
	1.00	558.0	19.83	11,660	75.5
	1.00	587.5	19.83	11,650	75.4
	1.00	587.5	19.83	11,650	75.4
	1.022	227.5	52.18	11,871	77.1
	1.022	227.5	52.18	11,871	77.1
	1.022	227.5	52.18	11,871	77.1
	1.035	442.5	28.36	12,549	77.1
	1.035	443.0	28.36	12,560	77.2
	1.035	443.0	28.36	12,560	77.2
0.090	1.01	657.5	19.83	13,038	72.8
	1.01	657.5	19.83	13,038	72.8
	1.01	657.5	19.83	13,038	72.8
	1.02	665.0	19.83	13,187	73.6
	1.02	665.0	19.83	13,187	73.6
	1.02	665.0	19.83	13,187	73.6
	1.007	637.5	19.83	13,038	72.8
	1.007	367.5	19.83	13,038	72.8
	1.007	637.5	19.83	13,038	72.8
	1.02	665.0	19.83	13,187	73.6
	1.02	665.0	19.83	13,187	73.6
	1.02	665.0	19.83	13,187	73.6
	1.005	657.5	19.83	13,038	72.8
	1.005	657.5	19.83	13,038	72.8
	1.005	657.5	19.83	13,038	72.8
	0.998	654.0	19.83	12,969	71.4
	0.998	654.0	19.83	12,969	71.4
	0.998	654.0	19.83	12,969	71.4
	1.025	253.0	52.18	13,200	73.7
	1.025	253.0	52.18	13,200	73.7
	1.025	253.0	52.18	13,200	73.7
0.107	1.022	275.0	52.18	14,350	69.2
	1.022	275.0	52.18	14,350	69.2
	1.022	275.0	52.18	14,350	69.2
	1.035	533.0	28.36	15,116	69.9
	1.053	532.5	28.36	15,102	69.8
	1.035	533.0	28.36	15,116	69.9
0.125	1.008	292.5	52.18	15,263	66.8
	1.008	292.5	52.18	15,263	66.8
	1.008	292.5	52.18	15,263	66.8
0.166	1.003	357.5	52.18	18,654	62.4
	1.003	357.5	52.18	18,654	62.4
	1.003	357.5	52.18	18,654	62.4
0.231	1.02	422.5	52.18	22,046	58.4
	1.02	422.5	52.18	22,046	58.4
	1.02	422.5	52.18	22,046	58.4

Digitized by Google

called to the excellent agreement in the observed results and those calculated by the formula. The observed values are given in the ninth column of Table VII, the calculated values in next to the last column and the percentage error referred to the observed values in the last column. This error is less than 1 per cent with the exception of the wire of radius 0.0535 cms.

Similar calculations were made for the alternating voltage and

TABLE VI—NEGATIVE CORONA

Diam. wire cms.	Density factor δ	D-C. volts	Mul. fac	Critical voltage (V)	Crit. surf. intensity (E)
0.074	1.003	462.5	28.36	13,117	80.6
	1.003	462.5	28.36	13,117	80.6
	1.003	462.5	28.36	13,117	80.6
0.090	1.03	517.0	28.36	14,662	77.8
	1.03	517.5	28.36	14,676	77.9
	1.03	517.0	28.36	14,662	77.8
	0.9907	503.0	28.36	14,265	75.6
	0.9907	502.5	28.36	14,230	75.6
	0.9907	503.0	28.36	14,265	75.6
0.107	1.003	560.0	28.36	15,880	73.5
	1.003	560.0	28.36	15,880	73.5
	1.003	560.0	28.36	15,880	73.5
1.125	0.992	587.0	28.36	16,657	68.6
	0.992	587.0	28.36	16,657	68.6
	0.992	587.0	28.36	16,657	68.6
0.166	1.003	667.5	28.36	19,214	64.3
	1.003	667.5	28.36	19,214	64.3
	1.003	667.5	28.36	19,214	64.3
0.231	1.001	431.0	52.18	22,440	59.3
	1.001	431.0	52.18	22,440	59.3
	1.001	431.0	52.18	22,440	59.3

the negative continuous voltage and the following constants were found.

Positive Corona

$A = 33.7$ $B = 11.5$

Negative Corona

$A = 31.02$ $B = 13.5$

Alternating-Current Corona

$A = 33.7$ $B = 12.6$

Digitized by Google

TABLE VII—CALCULATION OF CONSTANTS A AND B USING METHOD OF LEAST SQUARES. POSITIVE CORONA

r	δ	δ^2	δ^3	$\frac{\delta^3}{r}$	$\sqrt{\frac{\delta^3}{r}}$	$\frac{\delta}{r}$
0.037	1.02	1.0404	1.061	28.68	5.375	27.77
0.045	1.025	1.0506	1.076	23.9	4.885	22.7
0.0535	1.022	1.0445	1.068	19.97	4.47	19.14
0.0625	1.008	1.0161	1.025	16.4	4.05	16.12
0.083	1.003	1.0060	1.01	12.16	8.85	12.07
0.1155	1.02	1.0404	1.061	9.19	3.03	8.82
Σ		6.198			25.235	106.62

r	E obs.	δE	$\sqrt{\frac{\delta}{r}}$	$\sqrt{\frac{\delta}{r}} E$	E Calc.	Error % per cent
0.037	77.0	78.54	5.27	405.79	77.1	− 0.13
0.045	73.7	75.54	4.765	351.18	73.4	+ 0.41
0.0535	69.2	70.72	4.375	302.75	70.0	− 1.1
0.0625	66.8	67.33	4.015	268.2	66.7	+ 0.14
0.083	62.4	62.59	3.475	216.84	62.1	+ 0.48
0.1155	58.4	59.56	2.97	173.45	58.5	− 0.17
Σ		414.28	24.87	1718.21		

Resultant values $A = 437.7$, $B = 11.5$.

The values of E for the six sizes of wire calculated from the formula,

$$E = A + \frac{B}{\sqrt{d}}$$

using the above constants are given in Tables VIII and IX and plotted in Fig. 16.

TABLE VIII—ALTERNATING CURRENT

RELATION BETWEEN DIAMETER AND CRITICAL SURFACE INTENSITY

Diam. wire cms.	Density factor δ	Primary volts	Critical voltage (max.) (V)	Crit. surf. intensity E (kv.)/cm.
0.074	1.005	35.8	13,120	80.6
0.090	1.005	39.65	14,530	77.1
0.107	1.005	43.0	15,760	72.9
0.125	1.005	45.7	16,750	69.0
0.166	1.005	53.5	19,610	65.6
0.231	1.005	61.4	22,500	59.6

Digitized by Google

TABLE IX—CONTINUOUS CURRENT

(POSITIVE)

RELATION BETWEEN DIAMETER AND CRITICAL SURFACE INTENSITY

Diam. wire cms.	Density factor δ	Voltmeter reading	Critical voltage (V)	Crit. surf. intensity. E (kv.)/cm.
0.074	1.02	228.0	11,897	77.0
0.090	1.025	253.0	13,200	73.7
0.107	1.022	275.0	14,350	69.2
0.125	1.008	292.5	15,263	66.8
0.166	1.003	357.5	18,654	62.4
0.231	1.02	422.5	22,044	58.4
		(NEGATIVE)		
Diam. wire cms.	Density factor δ	Voltmeter reading	Critical voltage (V)	Crit. surf. intensity E (kv.)/cm.
0.074	1.003	462.5	13,117	80.6
0.090	1.03	517.0	14,662	77.8
0.107	1.003	560.0	15,880	73.5
0.125	0.992	587.0	16,657	68.6
0.166	1.003	677.5	19,214	64.3
0.231	1.001	431.0	22,490	59.3

In Table X is given a comparison of the results of observations on positive, negative and alternating-current corona with the results of the more important earlier researches. The formula,

$$E = A\,\delta + B\sqrt{\frac{\delta}{d'}}$$

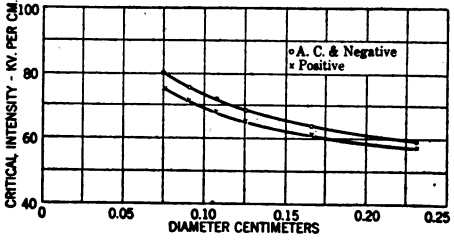


FIG. 16—CORONA VOLTAGES FOR ROUND CONDUCTORS

was used in all cases and the values of the constants A and B (as taken from the accounts of the different investigations and given in Table XI), substituted in order to obtain the values of E given in Table X.

Digitized by Google

The values of Table X for the alternating-current case are plotted in Fig. 17, those for the continuous current case (positive and negative) in Fig. 18.

TABLE X—COMPARISON OF RESULTS

CRITICAL SURFACE INTENSITY: KILOVOLTS PER CENTIMETER

Alternating current				Continuous current			
Diam. wire cm.	Whitehead	Peek	Whitehead & Brown	Whitehead & Brown +	Farwell +	Whitehead & Brown −	Farwell −
0.074	81.2	80.7	80.3	76.0	75.7	80.8	76.9
0.090	76.6	76.0	76.0	71.9	71.6	76.1	72.0
0.107	72.9	72.3	72.5	68.9	68.3	72.4	69.8
0.125	69.9	69.2	69.6	66.2	65.5	69.3	67.2
0.166	64.8	64.1	64.8	61.9	61.1	64.2	62.9
0.231	59.9	59.1	60.1	57.6	56.6	59.1	58.7

DISCUSSION

The fact that positive corona appears at a lower voltage than negative for the same size wire is in accord with the theory of secondary ionization if we assume that the negative ion is the principal ionizing agent. This is practically certain owing to

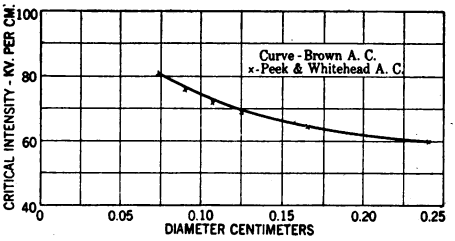


FIG. 17—CORONA VOLTAGES FOR ROUND CONDUCTORS

its energy of motion being greater than that of the positive ion under a given voltage gradient. If a difference of potential be applied between a wire and concentric cylinder the negative ions or electrons present in the air will move under the influence of the electric field. In so doing they will collide with the molecules of the air and they may or not produce other ions, depend-

Digitized by Google

ing upon their velocity. Now suppose the wire is positive. In this case the electrons will move inwards (toward the wire) and in so doing will move in the direction in which the intensity of the field is increasing. Thus new ions caused by collisions are formed in stronger and stronger fields and there is a consequent tendency to multiply to the concentration corresponding to corona formation. On the other hand if the wire is negative,

TABLE XI

Type of voltage	Name of investigator	Constants	
		A	*B*
a-c.	Whitehead	32	13.4
a-c.	Peek	31	13.5
d-c.	Farwell	31.6	11.9
d-c.	Farwell	35.0	11.4

the electrons will move outwards in the direction of decreasing field intensity. Only those which start from near the wire pass through the field of strong electric force so that the number of ions produced by collisions is much smaller than in the first case or a higher difference of potential will be required to produce enough ions by collision to start corona.

There is nothing new in the convergence of the curves for

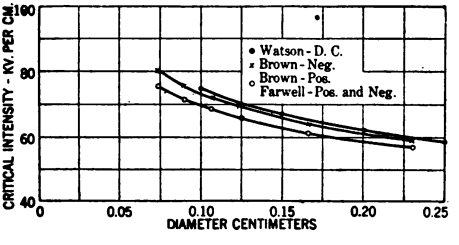


FIG. 18—CORONA VOLTAGES FOR ROUND CONDUCTORS

positive and negative corona. Schaffers, Watson, Mackenzie and Farwell all found evidences of this. As the meeting point is a function of the pressure and the diameter of the wire it is hard to compare the results of the different investigations on this basis. If the curves for positive and negative corona be extended they will meet at a point corresponding to a wire of diameter 0.285 cms.

Digitized by Google

Farwell states that the appearance of negative corona changes with increase of wire diameter and voltage, that the negative corona started with a bright spot or two on small wires followed by a continuous brush discharge as the voltage was increased and that for the larger wires the brush discharge appeared immediately upon reaching the critical voltage. In the present experiments by careful polishing and by raising the voltage in very small steps it was found possible to make the negative corona appear sharply as a continuous bluish glow on all the wires used. If the voltage was raised the smallest amount above that necessary to produce corona, the bluish glow collapsed to a purplish, point discharge and by lowering the voltage until the discharge just disappeared, a value of E was obtained in close agreement with Farwell. It is believed that this explains to some extent the low values obtained by Farwell in this case.

V. Experiments Testing the Theory of Corona Formation

Theory of the Start of Corona. According to the theory of secondary ionization, if a difference of potential be applied to a tube and concentric wire, the free electrons present in the air between will acquire a velocity under the electric field. The velocity will depend on the applied difference of potential and the "mean free path" of the electron. In order that corona form about the wire it is necessary that the electron acquire a velocity sufficient to produce other electrons by collision and that this process multiply to some state of concentration constituting corona. If the possible free path of the electron be limited in any way, a higher difference of potential will be required to give the critical velocity to the electron or to produce corona.

To test this theory concentric metal tubes with thin walls and insulating supports were introduced between the wire and the corona tube proper, in order to reduce the possible free path of the negative ion under the influence of the electric field and to observe the effect of this reduction on the value of V, the maximum value of the voltage required to produce corona. The great difficulty in such experiments is to determine when corona starts when the secondary tube is in place. On applying continuous voltage to the wire it was found that the voltage could be carried far above that required to start corona when the auxiliary tube was not in place without the slightest deflection of a galvanometer connected between the tube and ground and

Digitized by Google

without any indication of glow about the wire. It was at first thought that this could be explained on the hypothesis that the intermediate tube cut down the number of ionizing electrons already in motion in the outer portion of the field in accordance with the indications of the theory. An electrostatic voltmeter was then connected between the inner tube and the ground and the voltage again applied. On removing the voltage from the central wire the intermediate tube was found to retain a potential, as shown by the electrostatic voltmeter. An electroscope carrying a charge of known sign showed that the intermediate tube was charged to a potential of the same sign as the wire.

The failure of the galvanometer to deflect or of corona to appear was now easily explained; the presence of the high potential of the same sign on the intermediate tube lowered the potential gradient between the wire and the outer tube and therefore prevented the appearance of corona. That this is the correct explanation was shown by the absence of charge on the inner tube for voltages below corona. The conclusion therefore is that the corona may form at normal voltage, generating positive and negative ions. The ions of the opposite sign are attracted to the wire, those of like sign are driven to the intermediate tube where they raise its potential. This elevation of potential continues until it is sufficient to lower the intensity at the surface of the corona wire below corona forming value. The whole process is probably instantaneous.

Alternating current was then applied to the wire as it was thought that the inner tube would not acquire the charge noted above. The kenotron was used to rectify the current which flowed from the outer tube to the ground through the galvanometer, which was retained in these alternating-current experiments by reason of its value as a detector. Here again trouble was encountered due to a charge accumulating on the outer tube which disturbed the potential gradient and made it impossible to obtain corona even on raising the voltage far above that required to start corona when the outer tube alone was used and connected directly to ground.

The kenotron is a perfect rectifier and allows current to flow in one direction only. During the half cycle when the wire is positive a charge of the opposite sign is acquired by the tube through the kenotron. During the next half cycle the wire becomes negative, but a positive charge does not accumulate on the outer tube as the kenotron is conducting in but one direction.

Digitized by Google

The negative charge already there cannot return through the kenotron for the same reason and with each successive half-cycle more and more charge accumulates until the outer tube is considerably above ground potential, which lowers the effective potential gradient and prevents the formation of corona.

TABLE XII

INFLUENCE OF CONCENTRIC SCREENING TUBES ON CORONA VOLTAGE

(WITHOUT INNER TUBE)

A-C. volts	Shunt in ohms	$\frac{r_1 + r_2}{r_1}$
40.0	11.0	3.780
45.0	10.0	4.060
50.0	9.0	4.400
55.0	8.5	4.605
60.0	7.5	5.080
65.0	7.0	5.340
67.5	6.0	6.100
70.0	5.0	7.120
72.5	3.0	11.200

(WITHOUT INNER TUBE)

A-C. volts	Shunt in ohms	$\frac{r_1 + r_2}{r_1}$
40.0	12.0	3.56
45.0	11.0	3.78
50.0	10.0	4.06
55.0	9.3	4.30
60.0	8.7	4.52
62.5	8.3	4.69
65.0	7.6	5.03
66.0	6.5	5.71

Galvanometer Deflection Constant = 1 cm.
Visual Corona With Tube = 69.1
Visual Corona Without Tube = 64.2

A vibration galvanometer in the ground connection was next used and after many trials the results shown in Table XII and plotted in Fig. 19 were obtained. The instrument used was of the soft iron magnet type, in which a piece of soft iron is suspended by a silk fibre between the poles of a horseshoe magnet. A coil carrying the alternating current to be measured produces a field perpendicular to that of the magnet. The temporarily

Digitized by Google

magnetized piece of iron vibrates in synchronism with the alternating current and with an amplitude proportional to the strength of the current. The period of the moving system is adjusted to resonance by a magnetic shunt on the limbs of the magnet.

The first column gives the primary volts. The deflection of the galvanometer was held constant at one centimeter, by varying a non-inductive shunt across the instrument. The values of the shunt used are given in the second column. The total current flowing from the tube at any given voltage on the wire, is given by

$$i = \frac{r_1 + r_2}{r_1} + i_1 \qquad (9)$$

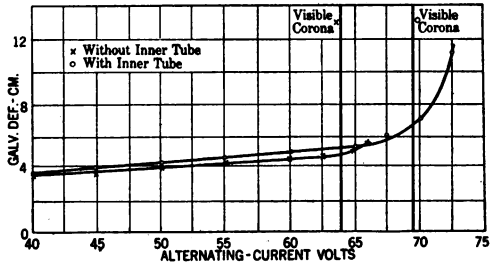


FIG. 19—EFFECT OF CONCENTRIC TUBES
Diameter outer cube = 6.98 cm.
Diameter inner tube = 2.448 cm.
Diameter wire = 0.231 cm.

where, r_1 = resistance of the galvanometer.
r_2 = resistance of the shunt.
i_1 = current through the galvanometer.

As the galvanometer current was held constant, the above equation reduces to

$$i = k\frac{r_1 + r_2}{r_1} \qquad (10)$$

The values of $\frac{r_1 + r_2}{r_1}$ are entered in the last column and the curve (Fig. 19) is plotted between $\frac{r_1+r_2}{r_1}$, which is proportional to the total current flowing, and the primary volts, on the transformer. The values at which visual corona appeared with and without this tube, which was 2.448 cms. in diameter, are given

Digitized by Google

in Table XIII and also marked on the curve. Three other tubes were inserted and observations made on the visual corona with and without them. These values are also entered in the table.

TABLE XIII

EFFECT OF THIN CONCENTRIC INSULATED TUBES ON CORONA VOLTAGE.

Diameter inner tube cms.	Primary volts
2.448	68.7
1.829	69.1
1.209	62.0 (Spark over)
0.605	.... (" ")
No tube	64.2
Diameter outer tube 6.98 cm.	Diameter wire 0.231 cm.

Discussion. The curve (Fig. 18) shows that the charging current is higher when the intermediate tube is in place as it should be owing to the increased capacity. The curves follow straight lines up to a value of voltage required to produce corona with no intermediate tube. An indication is given that the corona current rises more rapidly when the tube is not in place which is in accord with the theory. Corona appears at a higher value of voltage when either of the larger tubes is inserted which is in accord with the theory, as they cut down the number of ionizing electrons already in motion due to the outer portion of the field. If we omit the value obtained for the 1.209 cm. tube which is uncertain owing to spark over, we see that the smaller the diameter of the inner tube the higher the voltage required which is again in accord with the theory as the smaller the inner tube the more the accelerating path is cut down and the higher the voltage required to start corona. Because of the difficulty of maintaining the galvanometer deflection constant (it is affected by the slightest variation in the frequency) further modifications in the direction of constancy of frequency are necessary, and the experiments were terminated at this point. It is believed however that the above results are a reliable qualitative indication that corona voltage is elevated by an intermediate thin screen which serves as a barrier to the free passage of the ionizing electrons.

VI. CONCLUSIONS

1. The critical corona forming intensity at atmospheric pressure has been determined for six sizes of wire ranging from 0.074

Digitized by Google

to 0.231 cms. diameter for alternating and continuous potentials, in the same apparatus and under the same conditions.

2. The relation between critical surface intensity, that is, the intensity at which corona starts, and the diameter of a clean round conductor as found are expressed by the following laws:

$$\text{Alternating current}^* \quad E = 33.7\,\delta + 12.6\sqrt{\frac{\delta}{d}}$$

$$\frac{\text{Continuous current}^\dagger}{\text{Positive}} \quad E = 33.7\,\delta + 11.5\sqrt{\frac{\delta}{d}}$$

$$\frac{\text{Continuous current}^\ddagger}{\text{Negative}} \quad E = 31.02\,\delta + 13.5\sqrt{\frac{\delta}{d}}$$

3. Within the range of wires used the corona appears at a lower voltage when the wire is positive than when it is negative. The maximum excess of negative over positive observed was 6.3 per cent.

4. The values with alternating voltage coincide closely with those of negative continuous voltage.

5. The curves representing the positive and negative values converge as the diameter of the wire increases.

6. The observations on the positive and alternating-current corona are in substantial agreement with those of Farwell, Peek and Whitehead, although new values of the constants of formula (1) are indicated.

7. The observations on the negative corona give values higher than any heretofore obtained.

8. Experiments with concentric insulated screening tubes indicate that the critical corona forming intensity is raised by their introduction. (See Table XIII and Fig. 18.)

9. The results of the present investigation are in accord with the theory of secondary ionization as proposed by Townsend.

VII.—BIBLIOGRAPHY

1. Peek, F. W., Jr. Law of Corona, I. TRANS. A. I. E. E., Vol. XXX, 1889-1965, 1911. Law of Corona, II. TRANS. A. I. E. E., Vol. XXXI, 1051-1092, 1912. Law of Corona, III. TRANS. A. I. E. E., Vol. XXXII, 1767-1785, 1913.

*(See Table VIII and Fig. 15.)

†(See Table IX and Fig. 15.)

‡(See Table IX and Fig. 15.)

Digitized by Google

2. Whitehead, J. B. Electric Strength of Air, I. TRANS. A. I. E. E., Vol. XXIX, 1159-1187, 1910. Electric Strength of Air, II. TRANS. A.I. E. E., Vol. XXX, 1857-1887, 1911. Electric Strength of Air, III. TRANS. A. I. E. E., Vol. XXXI, 1093-1118, 1912.

Whitehead, J. B. and Fitch, T. T.—Electric Strength of Air, IV. TRANS. A. I. E. E., Vol. XXXII, 1737-1753, 1913.

Whitehead, J. B. and Gorton, W. S.—Electric Strength of Air, V. TRANS. A. I. E. E., Vol. XXXIII, 951-972, 1914.

Whitehead, J. B. Electric Strength of Air, VI. TRANS. A. I. E. E., Vol. XXXIV, 1035-66, 1915.

3. Watson, E. A. Atmospheric Loss under Direct-Current Pressures. *Electrician*, Vol. 63,828, 1909. Losses Due to Brush Discharge. *Electrician*, Vol. 64, 707, 1910.

4. Schaffers, V. La Conduction Electrique dans les Champs Cylindriques. *Comptes Rendues*, Vol. 157, 203-206, 1913.

5. Farwell, S. P. The Corona Produced by Continuous Potentials. TRANS. A. I. E. E., Vol. XXXIII, 1631-1671, 1914.

6. Dushman, Saul. A New Device for Rectifying High Tension Alternating Currents. *G. E. Review*. Vol. XVIII, No. 3, 156-167, 1915.

7. Hull, A. W. The Production of Constant High Potentials with Moderate Power Capacity. *G. E. Review.*, Vol. XIX, No. 3, 173-181, 1916.

8. Mackenzie, Donald. The Corona in Air at Continuous Potentials and Pressures Lower than the Atmosphere. *Phys. Review.*, Vol. V, April, 15, 1915.

9. Townsend, J. S. Theory of Glow Discharge from Wires. *Electrician* Vol. 71, 348, 1913. The Theory of Ionization of Gases by Collision.

10. Peek, F. W., Jr. The effect of High Continuous Voltages on Air Oil and Solid Insulations. PROC. A. I. E. E., June 1916, p. 773.

Laboratory of Electrical Engineering, John Hopkins University.

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 15, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

OSCILLATING-CURRENT CIRCUITS BY THE METHOD OF GENERALIZED ANGULAR VELOCITIES

BY V. BUSH

ABSTRACT OF PAPER

The oscillating-current circuit differs from the alternating-current circuit in that the sinusoids involved are damped.

In the same way that alternating-current theorems are obtained by generalizing direct-current theorems, it is possible to obtain oscillating-current theorems by still further generalization. This involves a generalized angular velocity and a generalized impedance which are complex quantities. Kirchoff's law may be thus generalized; and yields a simple method of determining the generalized angular velocities, and thus the frequencies and decrements, of free oscillation.

Since, in an oscillating-current circuit, there is no impressed voltage, the initial voltage present in the circuit must be used in determining the amplitudes of oscillation. This results in the introduction of a "threshold impedance" for use in determining the amplitudes, which is obtained by a single differentiation from the generalized impedance. Further direct-current rules may also be readily generalized for convenient use in the solution of oscillating-current circuits.

A simple example is given to show the method of procedure. The discharge of a leaky condenser through a reactor furnishes a second example which better illustrates the convenience of the method for numerical computations. As a third example the oscillation of a three section artificial cable under particular terminal conditions is chosen. The algebraical portion of this example is given in an appendix.

A list of symbols used will be found at the end of the paper.

INTRODUCTORY

IN SOLVING alternating-current networks it is convenient to make use of the pure imaginary, j. A sinusoidally varying quantity is represented by a revolving plane vector, and this in turn by the expression:

$$A\,\epsilon^{j\omega t}$$

A is the amplitude, and ω the "angular velocity" of the harmonic quantity or of the vector which represents it. When such expressions are combined according to the laws of algebra, true physical results are obtained because of the fact that harmon-

Manuscript of this paper was received October 9, 1916

Digitized by Google

ically varying quantities combine in accordance with the same laws as does this easily handled mathematical expression.

The use of this symbolism much simplifies the solution of such circuits; and much of this simplification results from the translation of direct-current rules into alternating-current rules by a proper exchange of terms. Thus Ohm's law is retained in its simplicity for the alternating-current case by the substitution of impedance for resistance; and the impedance of a circuit is defined in such a manner that the law will hold.

In oscillating-current circuits we consider the subsidence of a system from one state to another in the absence of impressed forces. The quantities involved vary in accordance with damped sinusoids. They may be represented by revolving plane vectors, which shorten exponentially as they revolve. Such a vector may be represented by the expression:

$$A\ \epsilon^{nt}$$

where n is a complex quantity of the form:

$$n \equiv -\alpha + j\omega$$

If we rewrite the expression in the form:

$$A\ \epsilon^{-\alpha t}\ \epsilon^{j\omega t}$$

it is seen to consist of the term of the alternating-current case multiplied by a damping factor. In such an expression the complex quantity n may be conveniently called a generalized angular velocity; and we may form from it generalized impedances, generalized admittances etc. in a manner exactly analagous to the alternating-current case.

The Frequencies and Decrements of Free Oscillation

Kirchoff's law, that the sum of the voltages around a closed path in a direct-current circuit is zero, is translated for use in alternating-current circuits by substituting the term impedance for resistance.

In similar manner it may be extended for use in oscillating-current circuits by putting in instead the term, generalized impedance, Since there are in this case no impressed voltages to be considered, the law may be more conveniently expressed by stating that the generalized impedance of a closed circuit to free oscillations is zero.

Digitized by Google

In the direct-current case the law furnishes an equation for determining an unknown constant. In the alternating-current case it may be used also to determine the frequency if everything else is known. In the oscillating-current case it may be used to determine the unknown generalized angular velocities of oscillation. This proposition was used by Rayleigh and Heaviside; and has been presented in more explicit form for convenient use by Eccles, Campbell, and Kennelly.†

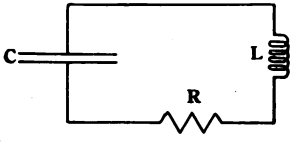


FIG. 1—SIMPLE SERIES CIRCUIT

One example will be sufficient to show the convenience of the law for practical use. Consider the series circuit of Fig. 1; a condenser of capacitance C, discharging through a reactor of inductance L and resistance R.

If we let n be the unknown generalized angular velocity, and apply the law to this circuit, we obtain

$$R + L\,n + \frac{1}{C\,n} = 0$$

From which, solving for n, there results:

$$n = -\frac{R}{2\,L} \pm j\sqrt{\frac{1}{L\,C} - \left(\frac{R}{2\,L}\right)^2}.$$

Assuming for convenience the quantity under the radical positive the angular velocity of free oscillation of this circuit is thus:

$$\sqrt{\frac{1}{L\,C} - \left(\frac{R}{2\,L}\right)^2}$$

or the frequency of oscillation is

$$\frac{1}{2\pi}\sqrt{\frac{1}{L\,C} - \left(\frac{R}{2\,L}\right)^2}$$

†Rayleigh, Theory of Sound.
Heaviside, Electromagnetic Theory, Vol. 2.
Eccles, *Electrician*, 1915. Phys. Soc. Proc. 24, 1912.
Campbell, TRANS. A. I. E. E., 1911. Vol. XXX, Part II, p. 873.
Kennelly, Proc. Institute Radio Engineers, 1915.

Digitized by Google

and the circuit has a decrement expressed by

$$\frac{R}{2L}$$

This familiar result, in which there may be three cases according to the sign of the quantity under the radical, is thus arrived at simply by the solution of an algebraic equation, without the necessity of employing the calculus.

The Amplitudes of Free Oscillation

If we attempt to translate Ohm's law in analogous manner, in order to arrive at the amplitudes of oscillation, a difficulty arises because of the fact that there is no impressed voltage present in an oscillating-current circuit. The impressed voltage, and the generalized impedance, are both zero; and their quotient is indeterminate.

There is however always an initial voltage present in such a circuit due either to an initial charge on a condenser, or to an initial current through a resistor. We seek then a function of the constants of the circuit, the generalized impedance Z, and the free generalized angular velocities n which shall give the amplitudes of oscillation when divided into the initial voltage.

Such a function will be found in the expression.

$$n\frac{dZ}{dn}$$

It may well be called on account of its peculiar properties the "threshold impedance" of the circuit.

If a circuit, initially containing a voltage E, be allowed to oscillate freely, the initial amplitude of current oscillation will be.

$$\frac{E}{n\frac{dZ}{dn}}$$

and the current expression accordingly, the sum of terms of the form

$$\frac{E}{n\frac{dZ}{dn}}\epsilon^{nt}$$

Digitized by Google

where each term is formed from one of the values of n resulting from the solution of the equation

$$Z = 0$$

Z is formed for the entire circuit, considering the element initially charged as the main branch.

The proof of this second law is neccesarily long; and may well be omitted in a paper of this character. The "threshold impedance" appears in papers by Heaviside.‡

When there is only a single frequency of oscillation present, as in the series circuit treated above, this second law is unnecessary; for the amplitude may be written down by inspection. In more involved networks, where several frequencies of oscillation exist simultaneously, the law furnishes a very convenient means of determining the amplitudes of the several terms in the solution.

Solution of Circuits

To completely solve an oscillating-current network, the method of generalized angular velocities thus requires the following steps:

1. Form the generalized impedance of the network, considering as the main branch the element initially charged.
2. Equate to zero, and solve for the generalized angular velocities of free oscillation: $n_1\ n_2\ n_3 \ldots\ldots$
3. Form the threshold impedance,

$$T = n \frac{dZ}{dn}$$

and insert the roots for n found above to form a series of values of the threshold impedance: $T_1\ T_2\ T_3 \ldots\ldots$

4. Divide the initial voltage E of the circuit by each of these values to form a corresponding set of amplitudes.
5. Write the oscillating-current expression in the form

$$i = \frac{E}{T_1} \epsilon^{n_1 t} + \frac{E}{T_2} \epsilon^{n_2 t} + \frac{E}{T_3} \epsilon^{n_3 t} + \ldots$$

‡Heaviside, Electrical Papers, Vol. 2, p. 373., Electromagnetic Theory. Vol. 2, p. 135.

Since this paper was written, an excellent proof of the second law by Wagner has appeared in *Archiv für Elektrotechnik*, 1916, Band IV, 5/6 Heft.

Digitized by Google

or more concisely,

$$i = \sum \frac{E}{T} \epsilon^{n t}$$

where the summation extends over the values of n found from the equation,

$$Z = 0$$

It will be noted that in the above the generalized angular velocities, generalized impedances, threshold impedances and generalized amplitudes are all complex quantities. Upon reducing the final expression to the usual trigonometric form by the use of the identity,

$$\epsilon^{j\omega} \equiv \cos \omega t + j \sin \omega t$$

the imaginary portions of the expression will of necessity cancel out, and leave a real trigonometric expression for the current.

Further rules for the examination of oscillating-current circuits may be readily obtained by generalization.

The current or voltage in a distant portion of the network may be found by combining the generalized impedances of the elements in the manner of simple resistances. Here as before the several terms of the current or voltage expressions are to be treated separately. An element has a generalized impedance corresponding to each free generalized angular velocity, to be used with the term of the current or voltage expression containing the same value of n.

When several stores of energy are simultaneously discharged, they may be treated separately and the results added.

Cases of oscillation under a suddenly applied steady electromotive force may be treated as the inverse of the discharge from the final state attained.

Oscillations under suddenly applied alternating voltages may be similarly treated; but the solution here rapidly becomes involved algebraically.

Examples of the Method. Three examples of the practical use of the method will be given. The first is very simple, to outline the procedure only. The second is of somewhat more complexity and is solved numerically. The third is intended to exemplify the method when several frequencies are present simultaneously. The inductively coupled circuit, which furnishes an excellent

Digitized by Google

example for this purpose, is reserved because of its interest for separate treatment. The method as used has been checked in numerous cases by the use of parallel solutions of the differential equation. Circuits such as that of example III have also been checked by the oscillograph and the artificial line at Harvard University.

I. Consider the circuit of Fig. 2: a condenser of capacitance C, initially charged to potential E, and discharging through simple resistance R.

The generalized impedance is,

$$Z = R + \frac{1}{C n} \qquad \text{ohms} \angle$$

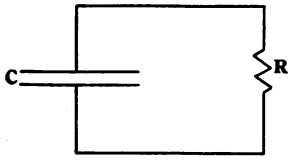


FIG. 2—CIRCUIT OF EXAMPLE I

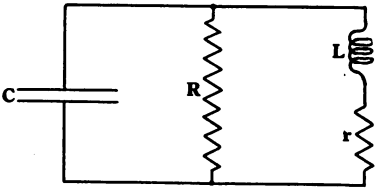


FIG. 3—CIRCUIT OF EXAMPLE II

Equate to zero, solve for n, and there results,

$$n = -\frac{1}{R C} \qquad \text{hyp. rad./sec.}$$

The threshold impedance is obtained from Z by differentiation;

$$T = n\frac{dZ}{dn} = -\frac{1}{C n} \qquad \text{ohms} \angle$$

For the free value of n found, this has the value,

$$T = -\frac{1}{C\left(-\frac{1}{RC}\right)} = R \qquad \text{ohms}$$

The current in the circuit is thus,

$$i = \frac{E}{T}\epsilon^{nt} = \frac{E}{R}\epsilon^{-\frac{t}{RC}} \qquad \text{amperes}$$

Digitized by Google

which may be checked by inspection and is the well known result.

II. As a better example, consider the network of Fig. 3; a condenser of capacitance C, initially charged to potential E, shunted by resistance R, and discharging through a coil of inductance L and resistance r.

Consider the condenser as the main branch, and form the generalized impedance:

$$Z_C = \frac{1}{Cn} + \frac{1}{\frac{1}{R} + \frac{1}{r + Ln}}$$

$$= \frac{R + r + Ln + RrCn + RLCn^2}{Cn(R + r + Ln)} \text{ ohms } \angle$$

Equate to zero, and solve for n, and there results,

$$n = -\left(\frac{r}{2L} + \frac{1}{2RC}\right) \pm j\sqrt{\frac{1}{LC} - \left(\frac{r}{2L} + \frac{1}{2RC}\right)^2} \text{ hyp. rad./sec.}$$

It may be noted in passing that if we had formed Z with another branch, say R, as the main branch;

$$Z_R = R + \frac{1}{Cn + \frac{1}{r + Ln}}$$

$$= \frac{R + r + Ln + RrCn + RLCn^2}{1 + rCn + LCn^2} \text{ ohms } \angle$$

the same roots for n would have resulted upon equating to zero. Owing to the difference in the denominator, however, Z_C should be used in forming the threshold impedance.

Form the threshold impedance:

$$T = n\frac{dZ_C}{dn}$$

$$= \frac{(R^2LC^2 - L^2C)n^2 - 2LC(R + r)n - C(R + r)^2}{C^2n(Ln + R + r)^2} \text{ ohms } \angle$$

Digitized by Google

For the sake of brevity let us now introduce the numerical values of the constants:

$$\begin{aligned} C &= 10^{-5} \text{ farad.} \\ L &= 0.1 \text{ henry.} \\ r &= 10 \text{ ohms.} \\ R &= 100 \text{ ohms.} \\ E &= 100 \text{ volts.} \end{aligned}$$

Substitute these values in the expressions above, and we obtain

$$n = -550.0 \pm j\,835.2$$

$$T = +101.2 \pm j\,153.8$$

We may now write the expression for the oscillatory current in the condenser,

$$i_c = \frac{100}{101.2 - j\,153.8}\,\epsilon^{(-550.0 + j\,835.2)\,t} + \frac{100}{101.2 + j\,153.8}\,\epsilon^{(-550.0 - j\,835.2)\,t} \text{ amperes } \angle$$

Note that in this expression each threshold impedance is associated with the term containing the generalized angular velocity from which it was derived.

Reduce the expression to trigonometric form, and combine terms, and it becomes,

$$i_c = 1.089\,\epsilon^{-550.0\,t} \sin(835.2\,t + 0.9882) \quad \text{amperes.}$$

Suppose we now wish the current in the coil. The condenser current divides between the other two branches in the ratio of their generalized admittances.

This ratio is,

$$\frac{R}{R + (r + L\,n)} \quad \text{numeric } \angle$$

or numerically,

$$0.550 \pm j\,0.8352 \quad \text{numeric } \angle$$

Multiply the exponential expression for i_c by this ratio; paying due attention to signs, and the coil current results:

$$i_L = (-j\,0.5443)\,\epsilon^{(-550.0 + j\,835.2)t} + (j\,0.5443)\,\epsilon^{(-550.0 - j\,835.2)\,t} \text{ amperes } \angle$$

Digitized by Google

and this may be reduced to,

$$i_L = 1.0886\ \epsilon^{-550.0t} \sin 835.2\,t \qquad \text{amperes.}$$

If we desire the voltage accross the inductance L, multiply i_L by $L\,n$, or by,

$$(55.0 \pm j\,83.52) \qquad \text{ohms} \angle$$

and obtain on reducing,

$$e_L = 108.9\ \epsilon^{-550.0t} \sin (835.2\,t - 0.9882)$$

and so on.

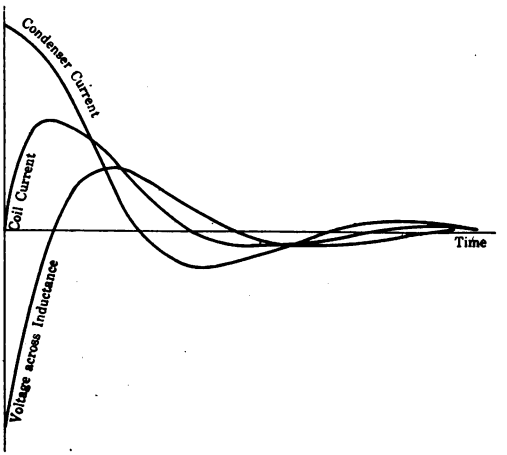


FIG. 4—DISCHARGE OF LEAKY CONDENSER—EXAMPLE II

These values are plotted in Fig. 4.

III. In the above example there are two conjugate roots for n, and hence a single frequency of free oscillation. The third example shows a case where more than one frequency is present. It is chosen from a series of solutions of the oscillations of the lumped artificial line under suddenly applied voltage. The three section artificial cable, grounded at one end, and suddenly connected at the other to a source of potential E, is chosen; as it illustrates the method with the least complexity of expression. The method proved adequate for the solution of the more general case with inductance present; and a series of solutions for various numbers of sections was used to derive a general expression for the lumped line and this type of transient. This expression,

Digitized by Google

compares with that of a smooth line under similar conditions, furnished a criterion of the value of experimental results obtained on the lumped line for this type of transient. A lower limit for the number of sections could be set if such results were to apply to the smooth line case with allowable error.

If the total cable capacitance is C, and resistance R, the three section artificial cable is as shown in Fig. 5.

Putting for brevity,

$$c = \frac{C}{3}$$

$$r = \frac{R}{3}$$

this circuit is equivalent to that of Fig. 6.

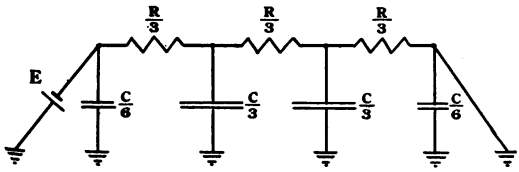


FIG. 5—THREE SECTION ARTIFICIAL CABLE

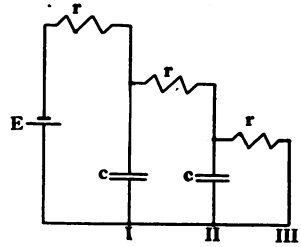


FIG. 6—CIRCUIT OF EXAMPLE III

This is a case of charge, to be treated as the inverse of discharge from the final state attained. We are interested merely in the current in branch III.

In the steady state there is a charge in condenser I with terminal voltage: $\frac{2E}{3}$, and in condenser II: $\frac{E}{3}$.

If we compute the discharge current of each of these condensers, by the method of the previous example, and find the proportional part of each which passes through branch III, we obtain respectively,

$$i_{III}' = \frac{E}{3r}\,\epsilon^{-\frac{T}{rc}} - \frac{E}{3r}\,\epsilon^{-\frac{3T}{rc}} \quad \text{amperes}$$

$$i_{III}'' = \frac{E}{6r}\,\epsilon^{-\frac{T}{rc}} + \frac{E}{6r}\,\epsilon^{-\frac{3T}{rc}} \quad \text{amperes}$$

Digitized by Google

In the steady state there is a current in branch III of value,

$$\frac{E}{3r} \quad \text{amperes}$$

Adding to this the negatives of the two discharge currents above gives the current in branch III due to the sudden application of voltage,

$$i_{III} = \frac{E}{3r} - \frac{E}{2r}\epsilon^{-\frac{t}{rc}} + \frac{E}{6r}\epsilon^{-\frac{3t}{rc}} \quad \text{amperes}$$

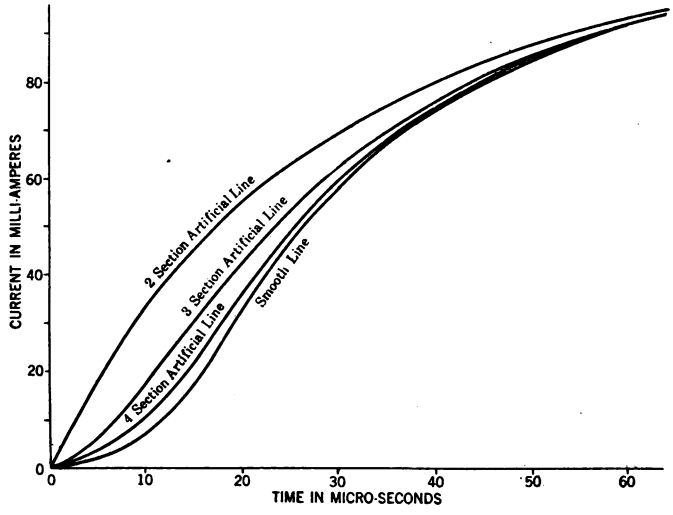


FIG. 7—RECEIVED CURRENT ON GROUNDED TRANSMISSION LINE—SMOOTH AND LUMPED LINES

Suddenly applied steady voltage at home end—20 volts
Line resistance 200 ohms—line capacity 10^{-6} farads

or in terms of total constants,

$$i_{III} = \frac{E}{R} - \frac{3E}{2R}\epsilon^{-\frac{9t}{Rc}} + \frac{E}{2R}\epsilon^{-\frac{27t}{Rc}} \quad \text{amperes}$$

A part of this example is treated more fully in the appendix.

A series of curves of this type, together with the smooth line curve from Kelvin's formula, are plotted in Fig. 7 for typical constants.

APPENDIX

ALGEBRA OF EXAMPLE III

In the steady state condenser I (Fig. 5) is charged to potential $\frac{2E}{3}$. The discharge of this condenser is computed as follows:

Digitized by Google

Consider branch I the main branch, and form the generalized impedance of the network by combining the generalized impedance of the elements in the manner of simple resistances.

$$Z_1 = \frac{1}{c\,n} + \cfrac{1}{\cfrac{1}{r} + \cfrac{1}{r + \cfrac{1}{c\,n + \cfrac{1}{r}}}} \quad \text{ohms}$$

or reducing,

$$Z_1 = \frac{r^2 c^2 n^2 + 4\,r\,c\,n + 3}{c\,n\,(2\,r\,c\,n + 3)} \quad \text{ohms}$$

Equate to zero, solve for n, and we obtain as free generalized angular velocities,

$$n_1 = -\frac{1}{r\,c}$$

$$n_1 = -\frac{3}{r\,c} \quad \text{hyp. rad./sec.}$$

Differentiate Z_1 with respect to n, multiply by n, and we obtain the threshold impedance. It is well to use for this purpose the form of Z_1 which is most easily differentiated.

$$T_1 = n\frac{d\,Z_1}{d\,n} = -\frac{1}{c\,n} - \frac{r^2 c\,n}{(2\,r\,c\,n + 3)^2} \quad \text{ohms.}$$

This threshold impedance has two values corresponding to the two free generalized angular velocities obtained above. Substituting them in and reducing, there results,

$$T_1 = 2\,r$$

$$T_2 = \frac{2\,r}{3} \quad \text{ohms}$$

Divide the initial voltage, $\frac{2E}{3}$, by each of these values of the threshold impedance to give the amplitudes of oscillation of the discharge current:

$$A_1 = \frac{E}{3\,r}$$

$$A_2 = \frac{E}{r} \quad \text{amperes}$$

Digitized by Google

Associate these amplitudes with the corresponding generalized angular velocities, and we have the discharge current of condenser I:

$$i_1 = \frac{E}{3r}\,\epsilon^{-\frac{t}{rc}} + \frac{E}{r}\,\epsilon^{-\frac{3t}{rc}} \qquad \text{amperes.}$$

This current divides among the several branches in proportion to their generalized admittances. The proportional part which passes through branches II and III is thus,

$$\frac{r}{2r + \dfrac{1}{cn + \dfrac{1}{r}}} \qquad \text{numeric}$$

and of this the part

$$\frac{\dfrac{1}{cn}}{r + \dfrac{1}{cn}} \qquad \text{numeric}$$

goes through branch III. The proportional part in branch III is thus,

$$\frac{r}{2r + \dfrac{1}{cn + \dfrac{1}{r}}} \times \frac{\dfrac{1}{cn}}{r + \dfrac{1}{cn}} \qquad \text{numeric}$$

or

$$\frac{1}{2rcn + 3} \qquad \text{numeric.}$$

This ratio again has two values corresponding to the two free values of n. Substituting these in we obtain for the ratio the two values,

$$1 \text{ and } -\frac{1}{3}$$

To multiply i_1 by the ratio, we multiply each term by the value of the ratio which corresponds to the value of n already involved

Digitized by Google

in the term. In this manner we obtain the portion of the discharge current of condenser I which passes through branch III:

$$i_{III}' = \frac{E}{3r}\epsilon^{-\frac{t}{rc}} - \frac{E}{3r}\epsilon^{-\frac{3t}{rc}} \quad \text{amperes.}$$

The discharge of condenser II is treated in like manner.

In this example the generalized angular velocities contain no imaginary part. In the more general case with inductance present, the generalized angular velocities are complex. The method of procedure is identical in the two cases; and the only difficulty results from the length of the expressions involved.

List of Symbols Employed

A = Amplitude of sinusoidally varying quantity.
j = The pure imaginary $\sqrt{-1}$.
ϵ = Naperian base. 2.718 . . .
ω = Angular velocity. Radians per second.
t = Time in seconds.
n = Generalized angular velocity. Hyperbolic radians per second. $\angle$
α = Logarithmic decrement. Hyperbolic radians per second.
C,c = Capacitance. Farads.
L = Inductance. Henries.
R,r = Resistance. Ohms.
Z = Generalized impedance. Ohms. $\angle$
T = Threshold impedance. Ohms. $\angle$
E = Initial potential. Volts.
e = Instantaneous potential. Volts.
i = Instantaneous current. Amperes
$\angle$ = Sign used to denote a complex quantity.

Digitized by Google

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 16, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

TRANSIENT CONDITIONS IN ASYNCHRONOUS INDUCTION MACHINES AND THEIR RELATION TO CONTROL PROBLEMS

BY R. E. HELLMUND

ABSTRACT OF PAPER

This paper discusses a number of transient conditions existing in asynchronous machines immediately after certain changes in the circuit connections are made. The advisability of considering these conditions in connection with the control layout for the purpose of eliminating bad effects caused thereby, is pointed out. The principal subjects considered are undesirable peak currents, which may be caused by the damping effect of the short-circuited rotor windings and the over-voltages, which are obtained with certain control arrangements.

DAMPING EFFECT OF CLOSED-CIRCUIT SECONDARIES

IT IS generally understood that the strong demagnetizing or damping effect of a short-circuited low resistance secondary of an inductance motor plays an important part during the starting from standstill, in so far as it counteracts and weakens the useful field of the motor to a considerable extent, resulting in very large starting current accompanied by relatively small starting torques. It is, however, not always fully realized that the same damping effect influences the motor working conditions in a number of other ways leading at times to very unfavorable effects, while serving to good advantage in other cases.

The fundamental fact to be considered in this connection is that any short-circuited low resistance winding will strongly oppose any change of flux interlinking with the winding. If the interlinking flux is of zero value, the building up of flux will be strongly opposed; on the other hand, if a certain flux happens to exist, its disappearance will be strongly opposed. This is due to the fact that any change of flux regardless of its cause or nature will at once induce a voltage in the short-circuited winding which, in turn, causes currents to flow. These currents are of demagnetizing direction if a flux is trying to build up or increase, and of a magnetizing direction if a flux is trying to dis-

Digitized by Google

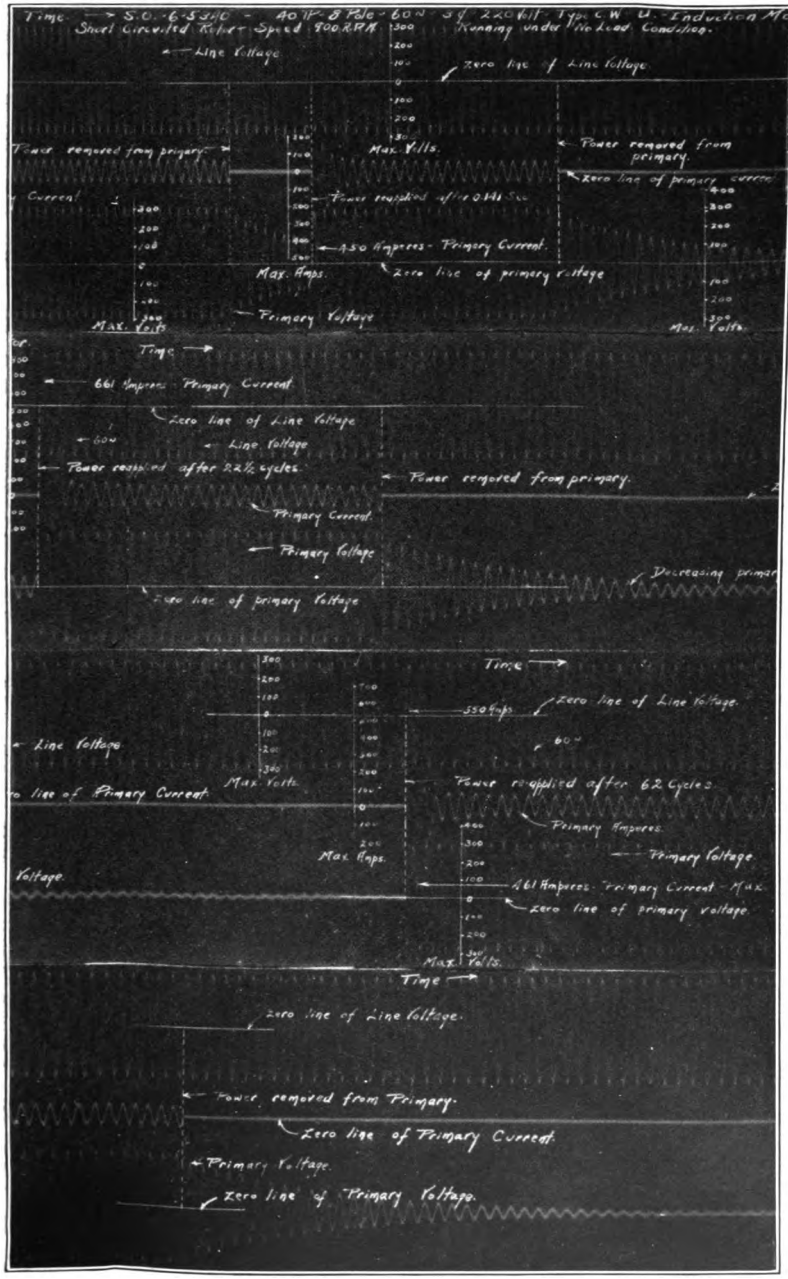
appear or decrease. This simple phenomenon should be kept in mind in connection with the design of the control with regard to every manipulation.

Let us consider, for instance, the most common method of starting induction motors by connecting the motor, first to a low-voltage tap of an auto transformer, subsequently disconnecting the motor and connecting it to the full line voltage. It is frequently assumed that the largest current surge is obtained with this method of starting when the motor is standing still and first connected to the low-voltage tap of the auto transformer, and that the current obtained when changing over to the full voltage corresponds to the current value indicated by the speed-current curve of the motor for full voltage. As a matter of fact, it is possible to obtain change-over currents far in excess of the original starting currents. The standard method for calculating the change-over current from the speed-current curve assumes that certain stable conditions exist with a rotating field and certain phase relations between primary and secondary currents fully established, a condition which, however, does not exist after the power supply to the motor has been temporarily interrupted during the change-over.

Various conditions may exist in the motor after a temporary interruption of power supply. When the low-voltage starting contacts are opened the rotating field set up in the rotor will be prevented from immediately disappearing by the previously mentioned damping effect of the rotor. The flux will continue to exist and rotate with the rotor for a certain period of time until the stored magnetic energy is used up by ohmic losses in the rotor, eddy currents, and the like. Since the rotating flux continues to exist it will, of course, continue to induce a voltage in the primary winding.

The oscillogram, Fig. 1, showing the motor voltage before and after the interruption of the primary contacts demonstrates this point. The size of the voltage maintained after interruption and the time during which an appreciable voltage is maintained, depends principally upon the amount of magnetic energy stored in the rotor at the time of interruption as well as upon the speed with which this energy is used up by losses in the motor. The losses depend largely upon the resistance in the secondary, and, therefore, the energy will be used up the quicker the higher the secondary resistance. The oscillograms, Figs. 1 and 2, were both taken on a 40-h.p., eight-pole, 60-cycle, wound-secondary motor.

Digitized by Google

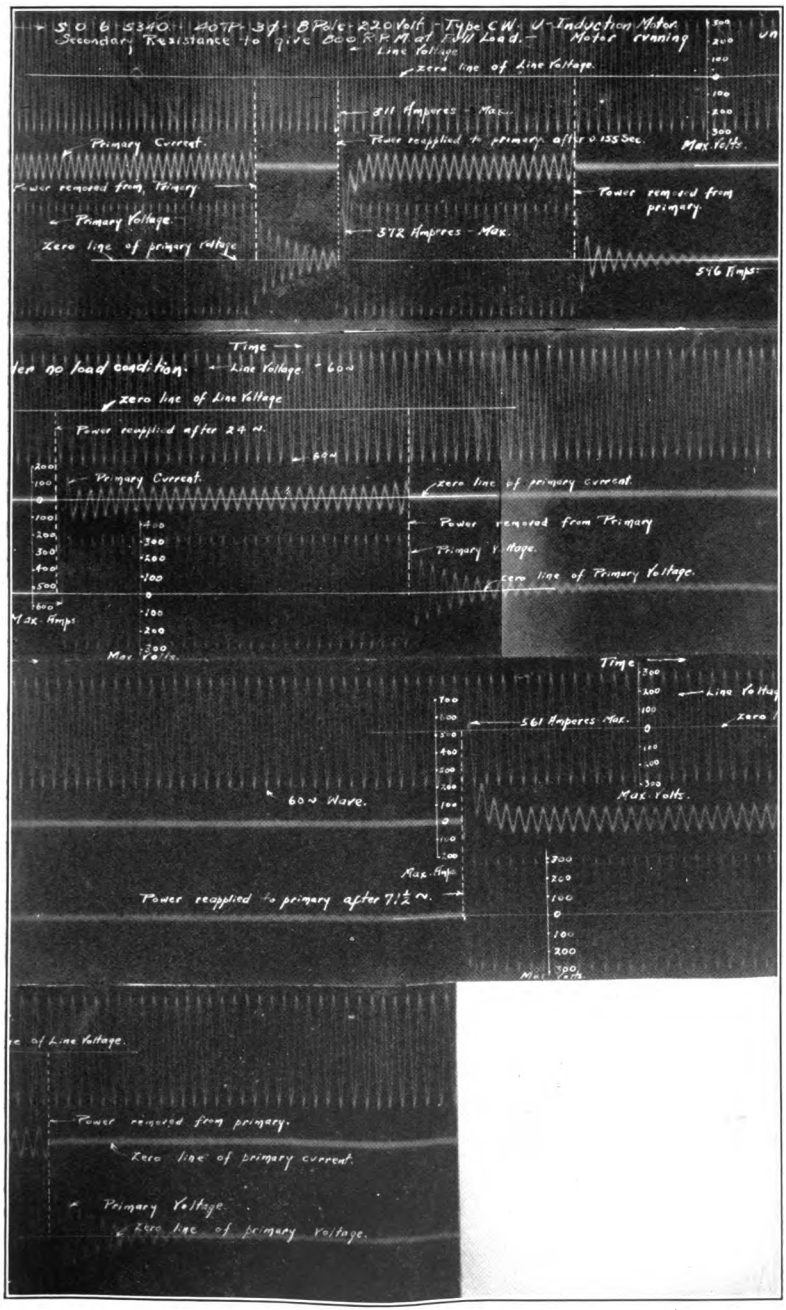


[HELLMUND]

FIG. 1

Digitized by Google

Digitized by Google



[HELLMUND]

FIG. 2

Digitized by Google

Digitized by Google

In case of Fig. 1, the rotor was short-circuited, while in case of Fig. 2, an external resistance was introduced to bring the motor speed down to 800 rev. per min.; the motor was running light in both cases. Comparision of the two figures shows plainly the effect of additional resistance upon the motor flux and voltage after the interruption. With the short-circuited rotor, the voltage drops to about 80 per cent after one cycle, to 75 per cent after two cycles and to 50 per cent after six cycles, while with the extra resistance in the rotor the corresponding values are about 60 per cent, 50 per cent and 25 per cent. With short-circuited rotor, the voltage practically dies out after about 35 cycles, or 0.6 second; with the extra resistance, only 15 cycles or 0.25 second are required. With short-circuited secondary, the motor voltage drops below half voltage after 7 cycles or 0.12 second, while with extra resistance only 1.5 cycles or 0.025 second are required.

Outside of the ohmic secondary resistance losses, there are as already mentioned other losses participating in a secondary degree in the consumption of the stored magnetic energy. The sudden changes of current in both members, and the corresponding changes in leakage fluxes are naturally accompanied by appreciable eddy losses in the conductors and the iron, hysteresis losses and the like; other core losses are caused by the rotation of the sustained field in the stator iron, etc.

The amount of stored magnetic energy is principally given by the size of the total flux in the machine, which, in turn, is the product of the magnetic densities and the magnetic sections.

A very simple consideration based* upon these fundamental facts leads to the conclusion that the flux and voltage will, in general, be maintained the longer, the larger the machine and the smaller the number of poles. While other factors, like mag-

*A fair idea of the principal factors regarding the amount and time of the maintained flux can be obtained by the following consideration. The principal energy dissipating losses, namely, the secondary resistance losses are, in general, proportiona to the 'ength L of the conductor per pole and inversely porportional to the available space for effective conductor section S in the rotor. The length of the conductor is, in turn, proportional to the length of the core l plus the pole pitch τ times a coefficient k. The pole pitch is given by

$$\tau = \frac{D\pi}{p}$$

where D is the air-gap diameter and p the number of poles; therefore, we

Digitized by Google

netic air-gap density, the copper space factor in the secondary winding, ratio of pole pitch to core width, etc., also have a certain influence, they do not vary over a wide range with up to date designs of small commercial motors. With larger motors now becoming more common in use, these points should also be given due consideration.

This general conclusion is well borne out by results obtained in practise. It has been observed, for instance, that an induction machine of about 1500 h.p., 25 cycles, 4-poles, would maintain a sufficient voltage to keep incandescent lamps luminous for seven seconds after the current supply was interrupted. On the other hand, a comparison of Fig. 3, which applies to a 5-h.p., 10-pole, 60-cycle motor, with Fig. 1 will show how a small machine maintains the flux and voltage only for a comparatively short period of time, the voltages following the circuit interruptions being about 70 per cent after one cycle, 55 per cent after two cycles and 25 per cent after six cycles, while

---

have an energy dissipating constant per pole

$$E_d = \left(l + \frac{D \pi k}{p} \right) \frac{1}{s}$$

The constant of stored energy per pole E_s is given by the pole face

$\frac{D \pi l}{p}$ multiplied by the air gap density B

therefore,

$$E_s = \frac{D \pi l B}{p}$$

Assuming a ratio $r = \frac{l}{\tau} = \frac{l p}{D \pi}$ or $l = \frac{r D \pi}{p}$ we have

$$E_d = \frac{D}{p} (r + k) \frac{\pi}{s}$$

and

$$E_s = D^2 \frac{\pi^2 r B}{p^2}$$

It is at once evident that insofar as the stored energy is proportional to the square of the diameter, while the energy dissipating factor grows only in linear proportion, that the maintained voltage will be in time and amplitude, the larger, the larger the machine. A further study of these expressions also indicates that the maintained voltage will be in general the larger, the larger the air-gap densities, the smaller the number of pole, etc.

Digitized by Google

the corresponding values in Fig. 1 are 80 per cent, 75 per cent and 50 per cent respectively.

The load condition of the motor will also have an influence upon the maintained flux and voltage, which, in general, decrease with increased load. This is due to several reasons, for instance the fact that on account of the primary drops, the secondary flux under load is smaller than the primary flux to start with, further, that on account of the larger load leakage fluxes, and their sudden changes, more energy is dissipated by eddy currents, etc.; again, the lower load speed will, with a given rotor flux, induce less voltage in the primary than the higher no-load speed. This may be demonstrated by comparing Fig. 1 with Figs. 4 and 5. These oscillograms were taken on the same motor, with no-load (Fig. 1) and $1\frac{1}{4}$ load (Figs. 4 and 5). Fig. 6, which was taken on a 25-h.p., 6-pole, 60-cycle motor under the same load conditions as Figs. 4 and 5 on the 40-h.p., 8-pole motor, is also of interest. A comparison of these figures shows that the lower rated 25-h.p. motor maintains the voltage and flux better than the 40-h.p. motor under the same load, which is due to the relatively lower rotor resistance usually incident to the smaller number of poles.

It is evident from the previous considerations that if the primary switches are reclosed after a temporary circuit interruption, the voltage and flux conditions of the motor may be widely different under various assumptions of the motor characteristics, the load, the time elapsed, etc.

Current Peaks with Closed-Circuit Secondaries and Zero Field

Let us consider first the case where the time of change-over from the low-voltage tap to full voltage is long enough to permit the rotor flux to reach zero value before the full voltage contacts are closed. It is evident from the fundamental facts stated in the beginning of the paper that upon closing the contacts, the damping effect of the rotor will prevent the quick establishment of the rotor flux on account of rotor currents setting up and strongly opposing the effect of the primary currents. This will also prevent all but the leakage part of the primary flux from building up quickly, so that at the first instant whatever counter e.m.f. exists has to be largely supplied by leakage fluxes no matter what the speed of the motor may be. In other words, very large primary currents are required at the first instant, no matter what the speed of the motor, to set up sufficiently large

Digitized by Google

leakage fluxes to induce the proper counter e.m.f. which must always be equal and opposite to the impressed e.m.f. after the circuit is closed. The amplitude of the current peaks when connecting the motor to the line with no flux in the secondary may, therefore, be the same near synchronous speed as it is at standstill for a given motor voltage. Since with the standard method of starting, the voltage after the change-over is usually larger than when starting from standstill, it is evident that the current peak after the change-over may be larger than when starting, assuming in both cases that the rotor field is zero at the time the connection is made. This does not necessarily mean that the effect upon the line and control apparatus at the time of the change-over is worse than at starting. In either case, the currents settle down within a short time to the values given by the speed-current curve. Since these values are usually larger for starting than at the change-over, and since the continuity of current peaks plays an important part in the effect upon the system, the resultant effect depends upon the individual case. It is, however, evident from the previous discussion that in a good many cases under the conditions discussed, the effect following the change-over may be worse than during starting.

The current peak obtained depends, of course, to a large extent upon the point of the impressed voltage wave at which the switches are closed. Moreover it can easily be seen that the damping effects opposing the building up of the flux are, in general, dependent upon the same factors as the damping effects maintaining the flux after the power supply has been interrupted, namely, the rotor resistance, etc. Furthermore, the leakage fluxes will have an important influence upon the current peaks as already pointed out. In general, it will be found that the size of the current peaks relative to the sustained current values is liable to be the larger, the larger the machine and the smaller the number of poles.

Fig. 7 shows a current peak of 778 amperes obtained with the 40-h.p., 8-pole motor which has a sustained standstill current of only about 425 amperes effective (600 amperes crest value) and about 115 amperes effective (163 amperes crest value) sustained current at the speed at which the test was made.

These conditions were obtained with an external resistance in the rotor circuit and it is evident that worse conditions may be experienced with the rotor short-circuited.

Digitized by Google

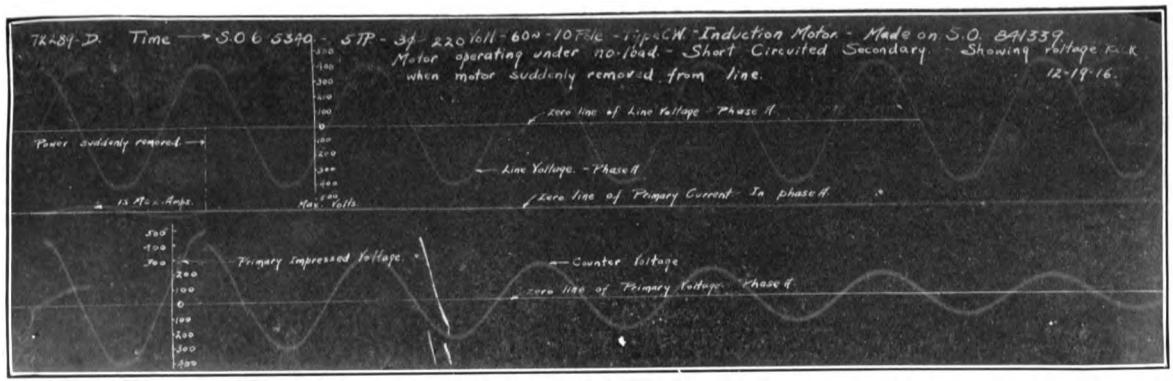
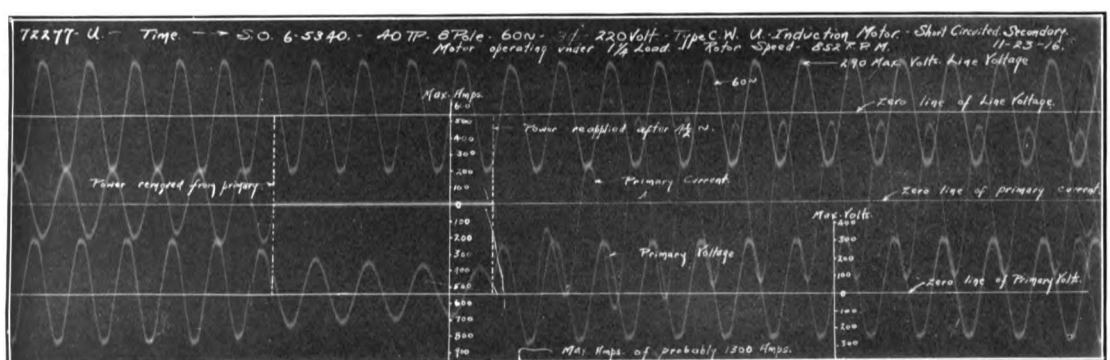

TR489-D. Time → S.O. 6 5340. - 5 TP - 3ϕ - 220 Volt - 60~ - 10 Pole - Type C.W. Induction Motor - Made on S.O. 84339
Motor operating under no load - Short Circuited Secondary - Showing voltage R.M.K
when motor suddenly removed from line.
12-19-16.
Power suddenly removed →
15 Max. Amps.
Max. Volts
Zero line of Line Voltage - Phase H
Line Voltage. - Phase H
Zero line of Primary Current In phase H
Primary Impressed Voltage
Counter Voltage
Zero line of Primary Voltage - Phase H

FIG. 3


TR277 U. Time → S.O. 6-5340. - 40 TP. 8 Pole. 60~ - 3ϕ - 220 Volt - Type C. W. U. Induction Motor. - Short Circuited Secondary.
Motor operating under 1½ Load. Motor Speed - 852 R.P.M. 11-23-16.
190 Max. Volts. Line Voltage
60~
Zero line of Line Voltage.
Max. Amps.
Power removed from primary →
Power reapplied after ½ ~.
Primary Current.
Zero line of primary current.
Max. Volts.
Primary Voltage
Zero line of Primary Volts.
Max. Amps. of probably 1300 Amps.

[HELLMUND]

FIG. 4

PLATE X.
A. I. E. E.
VOL. XXXVI, NO. 2

Digitized by Google

Digitized by Google

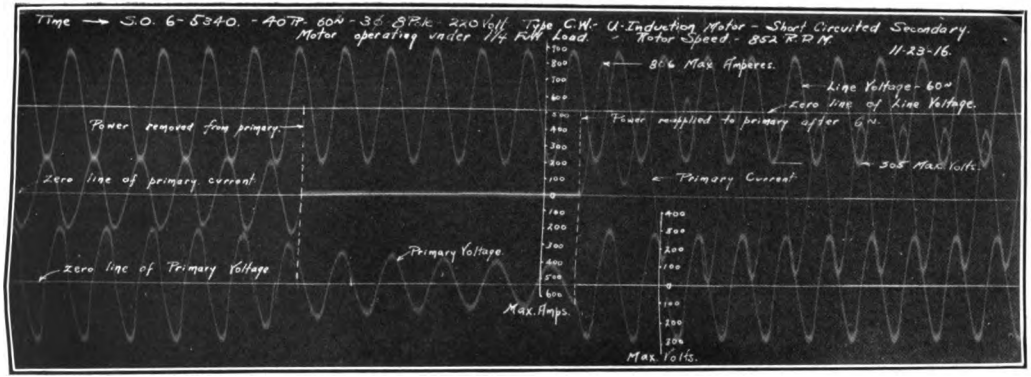
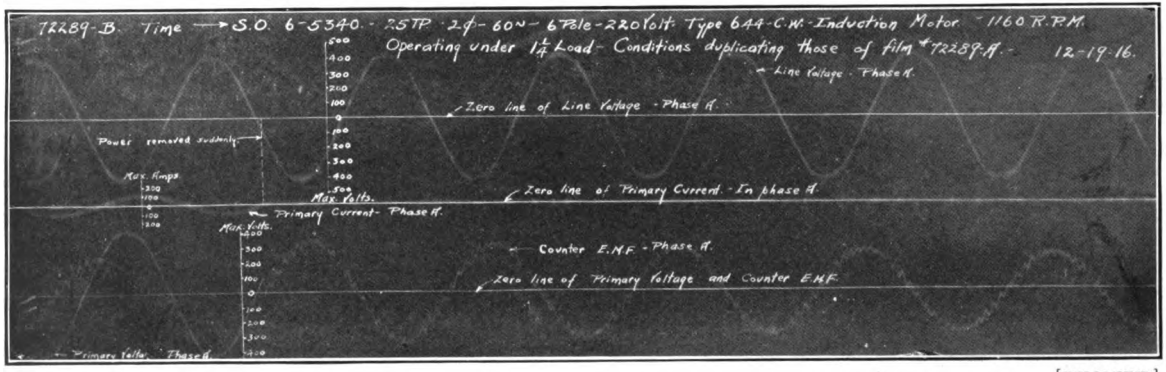

Time → S.O. 6-5340. - 40 TP. 60 N - 3 Ø 8 Pole - 220 Volt Type C.W.- U-Induction Motor - Short Circuited Secondary.
Motor operating under 1/4 F.W. Load. - Motor Speed - 852 R.P.M.
11-23-16.
806 Max. Amperes.
Line Voltage - 60 N
Zero line of Line Voltage.
Power removed from primary.
Power reapplied to primary after 6 N.
308 Max. Volts.
Zero line of primary current.
Primary Current
Zero line of Primary Voltage
Primary Voltage.
Max. Amps.
Max. Volts.

FIG. 5

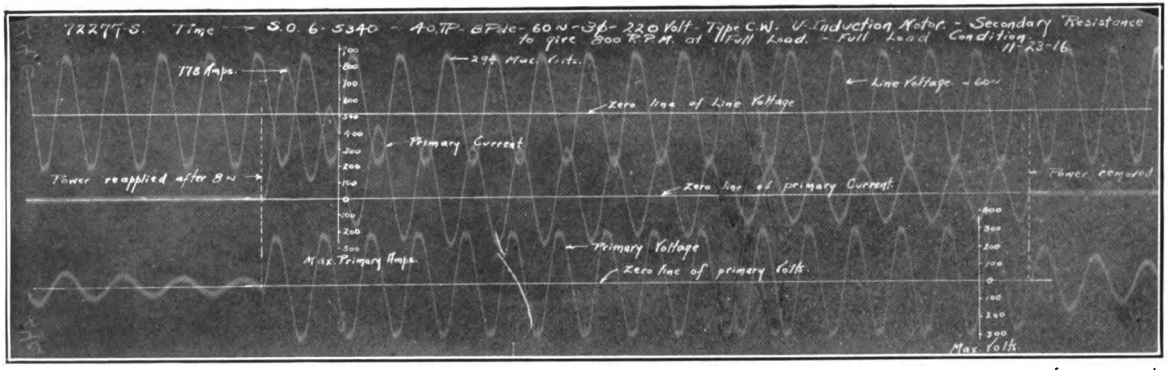

72289-B. Time → S.O. 6-5340. - 25 TP - 2 ϕ - 60 N - 6 Pole - 220 Volt Type 644 - C.W. - Induction Motor - 1160 R.P.M.
Operating under 1¼ Load - Conditions duplicating those of film # 72289-A. - 12-19-16.
Line Voltage - Phase A.
Zero line of Line Voltage - Phase A.
Power removed suddenly
Max. Amps.
Max. Volts.
Zero line of Primary Current - In phase A.
Primary Current - Phase A.
Max. Volts.
Counter E.M.F. - Phase A.
Zero line of Primary Voltage and Counter E.M.F.
Primary Voltage - Phase A.

[HELLMUND]

FIG. 6

Digitized by Google

Digitized by Google


12277 S. Time - S.O. 6-5340 - 40 HP - 6 Pole - 60 ~ - 3 ϕ - 220 Volt - Type C.W. V. Induction Motor - Secondary Resistance to give 900 R.P.M. at Full Load. - Full Load Condition
11-23-16.
178 Amps.
294 Max. Volts.
Line Voltage - Con.
Zero line of Line Voltage
Primary Current
Power reapplied after 8 ~
Power removed
Zero line of primary Current
Max. Primary Amps.
Primary Voltage
Zero line of primary Volts.
Max Volts.

[HELLMUND]

FIG. 7

PLATE XII.
A. I. E. E.
VOL. XXXVI, NO. 2

Digitized by Google

Digitized by Google

Current Peaks With Field Sustained by Closed-Circuit Secondaries

Let us consider now a case in which the change-over or current interruption is accomplished very quickly so that the contacts are reclosed before the rotor field has died out. Let us also assume at present that in such a case the load of the motor happens to be light, so that the rotor rotates at practically synchronous speed and that the rotor inertia is large enough so as to keep the motor speed practically unchanged during the power interruption. With these assumptions, the counter e.m.f. of the stator induced by the flux rotating with the rotor will maintain a synchronous relation with the line e.m.f., and if the contacts are reclosed the counter e.m.f. of a certain amount and proper phase relation already exists keeping the initial current rush down to a very small value. In such cases, it may be that the initial current closely agrees with the current given by the speed-current curve of the motor. If, on the other hand, the motor is

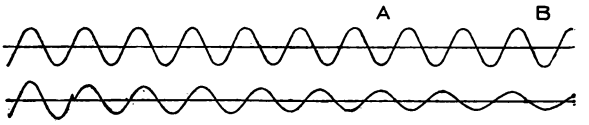


Fig 8

heavily loaded, so that its rotor speed is appreciably below synchronism, and if the rotor has small inertia so as to permit a further drop in speed during the current interruption, the voltage induced by the flux rotating with the rotor speed will fall quickly out of synchronism with the line voltage. Such a condition is demonstrated in Fig. 8 which has been traced from an oscillogram similar to that of Fig. 6 in order to show the conditions clearer than is possible with the oscillograms themselves, which were unfortunately taken with the voltage elements connected in opposite directions (see Fig. 6) or to different phases (see Figs. 4, 5 and 7).

If we assume, for instance, that the stator voltage has slipped $\frac{1}{2}$ cycle relative to the line voltage as at the point A when the contacts are closed, we have a condition very much the same as obtaining in a synchronous machine connected to the line when out of synchronism, and it is evident that very large currents may flow temporarily because it is not only necessary to build up a rotor flux against the damping effect of the secondary wind-

Digitized by Google

ing, but it is necessary to first reduce the existing flux to zero and build up the flux in the opposite direction. It is considered poor practise to connect large synchronous motors to the line before establishing synchronism, and equivalent precautions should be taken when starting large induction motors to prevent severe burning and arcing.

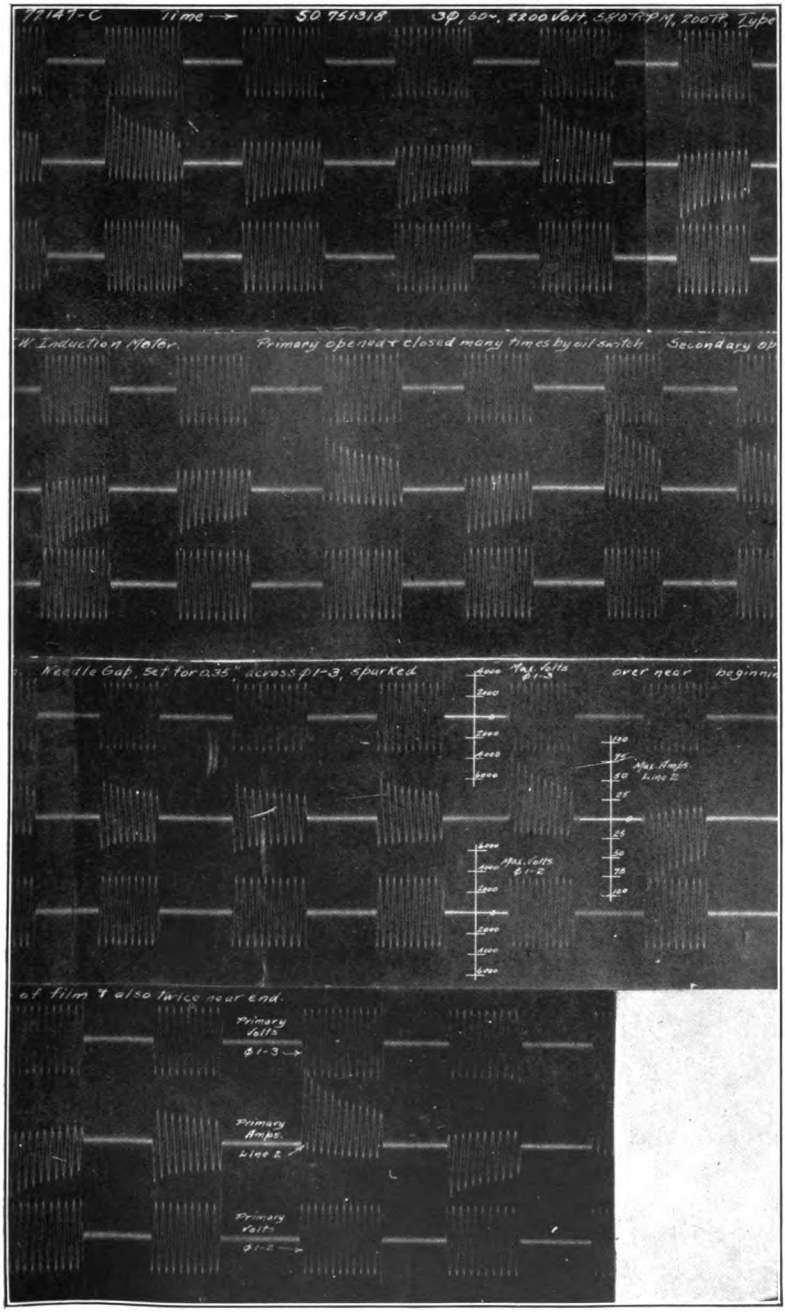
The author was not fortunate enough to get an oscillogram showing the closing of the circuit at the most unfavorable point. This is pretty hard to do in view of the fact that very small fractions of a second bring about important differences in the conditions. If the circuit were closed, for instance, at point *B* in Fig. 8, that is only 0.12 second later, the voltages are again in phase and fairly favorable current conditions would obtain.

Fig. 4 and Fig. 5 taken with the 40-h.p., 8-pole motor show the highest current peaks tested, giving about 1300 amperes (estimated) and 806 amperes respectively, as compared with a sustained standstill current of 450 amperes effective (635 amperes crest value), and a sustained value of 150 amperes effective (212 amperes crest value) for the speed at which the test was made.

Current Peaks with Open-Circuit Secondaries

The previously discussed current peak values as affected by the damping currents in the rotor should not be confused with the transient current peaks obtained when connecting any inductive piece of apparatus to an a-c. voltage, even when there are no damping effects. Figure 9 shows, for instance, the current of a 200-h.p. motor, when connected to the line with open secondary. It will be seen that some of the transient peak values are about 3.5 times as high as the sustained magnetizing current. They are, however, only 150 per cent of the full-load current, or 26 per cent of the sustained standstill current of the same motor (crest values in all cases). These currents are, therefore, small in comparison with the previously discussed transient current peaks obtained with the damping effect of a short-circuited rotor, and they are, therefore, of lesser importance in connection with the design of the control arrangements. In this connection it might be mentioned that motors with open external secondary circuits, should not be always considered as entirely free from damping effects. A delta connected secondary, for instance, may develop appreciable transient damping currents under certain conditions, even with open secondary con-

Digitized by Google



[HELLMUND]

FIG. 9

Digitized by Google

Digitized by Google

trol switches, especially when temporarily only one of the primary circuits of a polyphase motor is closed, as is frequently the case on account of the fact that the switches do not all come in simultaneously.

Effect of Secondary Damping Currents Upon Operation and Design

While the damping effect of the rotor has as previously pointed out, in many cases unfavorable effects upon the system and the control apparatus, it has at least the advantage that both during starting and after the change-over with the rotor field previously reduced to zero, the torque of the motor picks up gradually because torque is impossible without a secondary field. Any harmful effects which might be caused by too sudden picking up of the torque are, therefore, avoided.

In view of the fact that with a short-circuited rotor certain large peak current conditions cannot altogether be avoided, even if the rotor flux is zero to start in with, it is evident that control apparatus, as well as all other parts of the system must be designed to stand these peak currents. It is also evident that the reclosing of the circuit before the rotor flux has died out should be avoided in control arrangements for large squirrel-cage motors, because under certain conditions this is not only liable to give current peaks much larger than otherwise obtained but also liable to give under slightly different conditions a too sudden picking up of large torques, which may result in damage to the motor and the driven machinery. When starting a motor at reduced voltage, a closed circuit transition to the full-voltage tap by means of preventive resistances or inductances is, of course, the safest, especially in the case of large motors.

In the case of wound-secondary motors, current peaks can best be reduced by always introducing a resistance into the secondary before closing or reclosing the primary circuits.

In case of the control of induction apparatus for railway work, the damping effect of the secondary of induction apparatus is of special importance. It may happen in this case, for instance, that the trolley bounces, interrupting the power for a very small interval of time, leading to very severe rushes of current when connections are reestablished. In some experimental tests conducted on a large induction phase converter, explosive arcing was repeatedly established. In actual practise arrangements are made to introduce temporarily by means of a relay an induc-

Digitized by Google

tance into the converter circuit upon any power interruption, so that the current peaks are held down when the power comes on again within a short interval of time. Another relay interrupts the circuits completely if the power stays off long enough to permit an appreciable decrease in speed. It is of interest in this connection, that it is not possible to employ a no-voltage relay for the quick acting switch introducing the inductance, because the induction machine does not lose its voltage for sometime after the power interruption as previously discussed; it is, therefore, necessary to use a current relay in the single-phase circuit. The fact that the voltage is maintained sometime after the interruption, is used, however, to good advantage for operating the switches interrupting the circuit completely after a certain interval of time, by means of a voltage relay connected across the induction machine, which drops out about 5 to 10 seconds after the power interruption.

There is another case that should be considered in connection with the effect of the short-circuited rotor in maintaining the flux and motor voltages for a certain interval of time, after the primary has been disconnected. Certain switching arrangements are sometimes used, to change from high-speed to low-speed connections, for instance, that are not designed to operate under current and voltage. Care should be taken that none of the secondary motor circuits are interrupted by such switch arrangements, even after the primary current interruption, until the secondary damping currents have died out.

Over-Voltages with Open-Circuit Secondaries

Another subject related to transient conditions in the machine which is worth while considering is that of over-voltages which may be caused by improper control arrangements and result in insulation breakdowns in the motor and in the control.

Let us consider the case of a wound secondary motor with the control arranged to break, first, the secondary circuit and subsequently the primary circuit. In this case the primary switches break nothing but the magnetizing current. The natural tendency of the a-c. arc is of course to rupture when the current has reached zero value, or thereabout, following the regular sine curve. Since with open secondary circuit the flux is about proportional to the primary current, it may be assumed that the flux at the time of current interruption is zero. If this is the case, no further change of flux has to take place and no

Digitized by Google

over-voltages would be liable to occur. It has been found, however, by tests that the cooling effect of the oil or air upon the interrupting arc makes the current value of the last half cycle die out quicker in line with a curve A, Fig. 10, instead of in line with the regular sine curve B. Assuming that the flux follows the same curve, we obtain voltage values as indicated by curve C instead of those shown by D corresponding to a sine flux curve. It will be seen that under the assumptions made an over-voltage of four times the normal crest voltage is obtained. These voltage surges when obtained in practise are of such short duration that their full amplitude cannot be measured by the

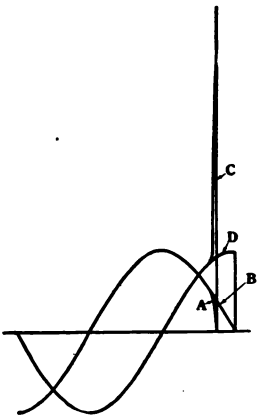


FIG. 10

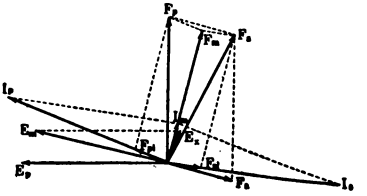


FIG. 12

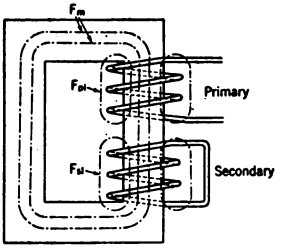


FIG. 11

standard oscillograph tests; voltages up to four times normal voltage have, however, been shown by spark-gap tests.

OVER-VOLTAGES WITH CLOSED-CIRCUIT SECONDARIES

Since, as previously pointed out, the short-circuited secondary has a tendency of preventing any sudden changes in flux, the idea naturally suggests itself to open the primary circuit with the secondary short-circuited, thereby avoiding sudden dying out of the fluxes and over voltages. This is an excellent remedy as long as the rotor fluxes and stator fluxes are practically identical, as for instance, at no load and light loads where the leakage fluxes are practically negligible, as compared to the main flux common to both stator and the rotor.

Digitized by Google

With heavy overloads cases are, however, possible where short-circuited rotors are not altogether a safe remedy against over-voltages because the leakage fluxes may be relatively large enough to cause trouble in spite of the favorable damping effect of the rotor. This may be demonstrated by Figs. 11 and 12. An induction motor is in all respects very similar to a transformer except that the leakage fluxes form a larger percentage of the total fluxes. For the purpose of demonstration Fig. 11 shows, therefore, a transformer with the mutual flux F_n, the primary leakage flux F_{pl} and the secondary leakage flux F_{sl}. If now the secondary winding is short-circuited and the primary interrupted, the damping effect of the secondary winding will tend to maintain constant the flux interlinking with the secondary winding. On the other hand, it is evident that the primary leakage flux F_{pl} will die out as soon as the circuit is interrupted. Not only that but by far the largest amount of the secondary leakage flux will choose the easiest path through the primary winding, there being no more counteracting ampere turns flowing in the primary winding and the path through the main iron being of exceedingly small reluctance as compared with the reluctance of the leakage path. It is obvious, therefore, that upon interruption of the primary current we will not only have the primary leakage flux disappear suddenly but add the secondary leakage flux which is practically of opposite direction to the mutual flux in the primary coil. The total flux change in the primary winding is therefore about equivalent to the total leakage and while this amount is only a part of the total flux, the change being opposed only by eddy losses, etc., in the iron takes place so quickly, that voltages of pretty high amplitude may be induced.

The change in flux is further demonstrated by the vector diagram of Fig. 12. The vector E_p may be the impressed primary voltage and I_p the primary current lagging by a certain angle. The primary current sets up, of course, a leakage field in phase with the current which may be represented by the vector F_{pl}. This vector induces a reactance voltage E_x which must be subtracted from the impressed voltage E_p to give the voltage E_m induced by the mutual flux. The vector F_m shifted 90 deg. against this voltage represents the mutual flux. By combining this flux with F_{pl} we obtain the total primary flux F_p. The resultant magnetizing current I_m is, of course, in phase with the mutual flux and the resultant of the primary current I_p and the

Digitized by Google

secondary current I_s. The secondary current I_s sets up the secondary leakage flux F_{sl} which combined with F_m gives the total secondary flux F_s. If the primary circuit is now interrupted and if it is assumed for the moment that the damping effect maintains the secondary flux absolutely constant, and if we further assume that practically all of that flux swings into the primary winding, we see that the primary flux suddenly has to change from the value F_p to the value F_s. This is equivalent to the sudden addition of a flux vector F_a to the vector F_p to give the vector F_s. While this flux F_a which has to be added suddenly is smaller than the primary flux, the rate of change is

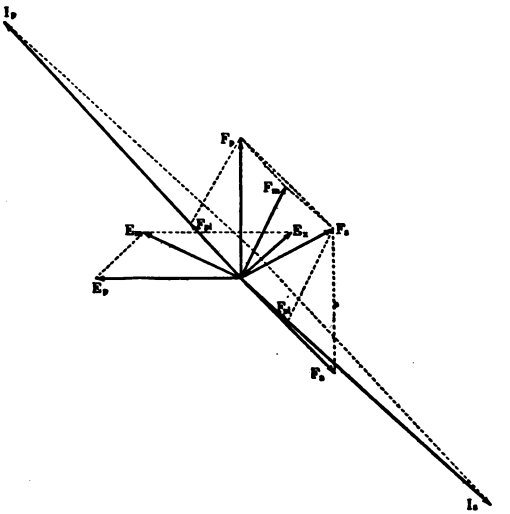


FIG. 13

so much quicker that voltages in excess of the normal primary voltage may be induced in the stator.

The case shown in Fig. 12 is, of course, extreme, if a normal load is considered, but the relative sizes as shown may very easily obtain in standard motors with heavy overloads.

While the bad influence of leakage fluxes exists only with severe overloads, such a case is nevertheless of practical importance in so far as it is just in connection with heavy overloads that the primary circuit is frequently interrupted by overload circuit breakers while the motor is pulling out and nearing standstill conditions. Fig. 13 shows a diagram of the vector relation applying to such a case and demonstrates plainly that the sudden

Digitized by Google

flux changes taking place in this case may closely approach values equivalent to the total primary flux.

Most of the oscillograms previously referred to plainly indicate the sudden phase shift of the stator flux when the power is interrupted, see for instance, Figs. 4, 5, 6 and 7.

As previously mentioned, it is not possible to show the full extent of the voltage surges by oscillograph test. Some indication of them is shown, however, in Figs. 14 and 15, which were taken at standstill when the leakage fluxes have their maximum value while the mutual flux is relatively small. The oscillograms show in this case over-voltages up to 70 per cent above the crest value of the normal voltage.

In view of this, it would seem advisable in case of large high-voltage squirrel-cage motors to use circuit breakers which interrupt the current in two or more steps by introducing resistance or inductance into circuit before the final break is made. In case of wound-secondary motors it is good practise to introduce part or all of the starting resistance into the circuit before breaking the primary circuit. This will temporarily reduce the load of the machine, because the motor speed cannot drop quickly enough on account of the rotor inertia, to give at once heavy torques with the increased resistance. Therefore, the load currents and with them the leakage fluxes, are temporarily reduced to a minimum value, and if the primary circuit is opened before the rotor speed has dropped, we have the favorable damping effect of the closed rotor circuit to a certain extent, without the unfavorable effect of large leakage fluxes.

Voltages up to double the normal peak voltage have been tested with the spark gap and appreciably higher voltages seem to be quite likely in certain cases.

The condition just described with short-circuited rotors is most likely to occur in machines with relatively large leakage fluxes, that is, principally in low-speed machines with a large number of poles. Such machines have not only relatively large leakage fluxes, but they are also most likely to pull out under heavy overloads, since they usually have rather small pull-out torques.

It appears further from the previous considerations, that over-voltages are liable to occur if a motor with short-circuited rotor is started by closing the primary switches, and if these switches are opened again, before the motor has assumed normal speed and load conditions. The reopening of starting switches, before

Digitized by Google

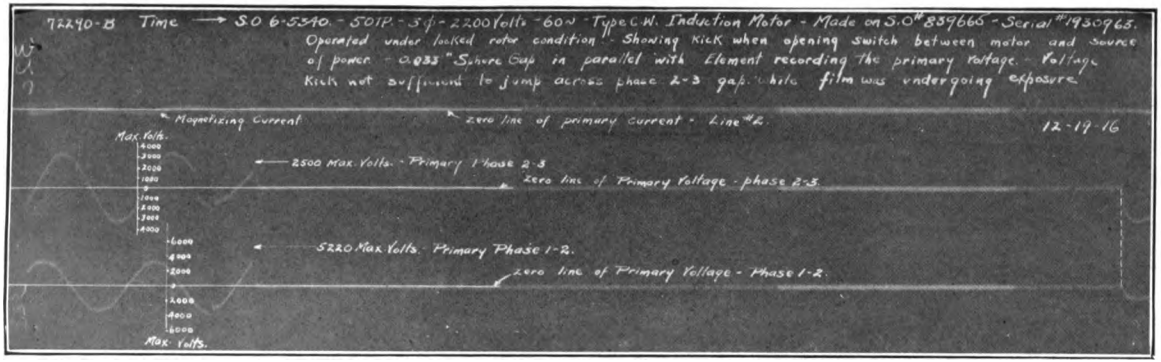
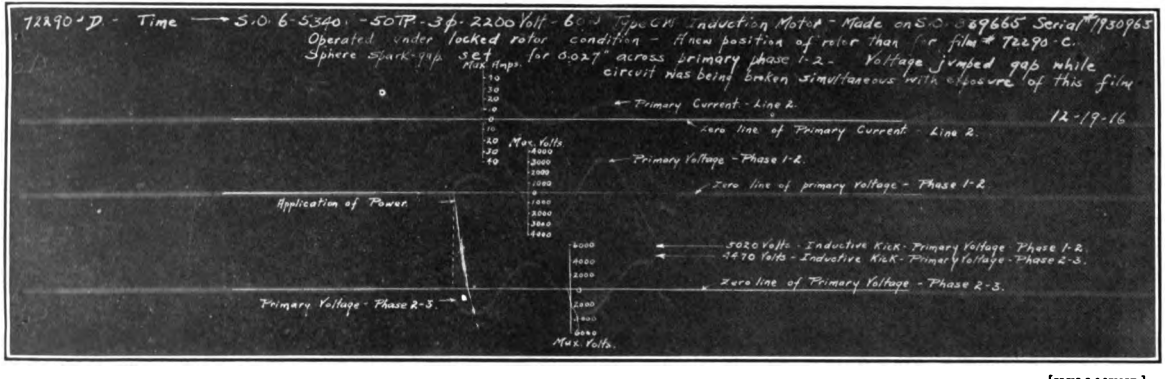

72290-B Time → S.O. 6-5340. - 50TP. - 3φ. - 2200 Volts - 60~ - Type C.W. Induction Motor - Made on S.O.# 839665 - Serial #1930965.
Operated under locked rotor condition - Showing Kick when opening switch between motor and source of power - 0.033" Sphere Gap in parallel with Element recording the primary voltage. - Voltage Kick not sufficient to jump across phase 2-3 gap while film was undergoing exposure.
Magnetizing Current
Zero line of primary current - Line #2.
12-19-16
Max. Volts.
2500 Max. Volts. - Primary Phase 2-3
Zero line of Primary Voltage - phase 2-3.
5220 Max. Volts. Primary Phase 1-2.
Zero line of Primary Voltage - Phase 1-2.
Max. Volts.

FIG. 14


72290-D - Time → S.O. 6-5340. - 50TP - 3φ - 2200 Volt - 60~ Type C.W. Induction Motor - Made on S.O. 839665 Serial #1930963
Operated under locked rotor condition - A new position of rotor than for film # 72290-C.
Sphere Spark-gap set for 0.027" across primary phase 1-2. - Voltage jumped gap while circuit was being broken simultaneous with exposure of this film
Max. Amps.
Primary Current - Line 1.
12-19-16
Zero line of Primary Current - Line 2.
Max. Volts
Primary Voltage - Phase 1-2.
Zero line of primary voltage - Phase 1-2.
Application of Power.
5020 Volts - Inductive Kick - Primary Voltage Phase 1-2.
4470 Volts - Inductive Kick - Primary Voltage - Phase 2-3.
Zero line of Primary Voltage - Phase 2-3.
Primary Voltage - Phase 2-3.
Max. Volts.

[HELLMUND]

FIG. 15

PLATE XIV.
A. I. E. E.
VOL. XXXVI, NO. 2

Digitized by Google

Digitized by Google

the motor has speeded up should, therefore, be avoided and the switches should be designed to be positive in their action and to make bouncing impossible.

Over-Voltages with Over-Synchronous Speeds

Another instance in which over-voltages in the rotor circuit of wound-secondary motors have been experienced, is in the case

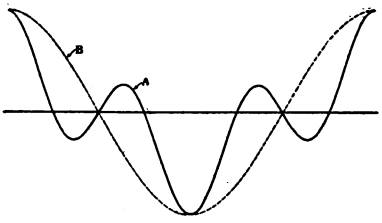


Fig. 16 a

A—Flux Interlinking with Secondary Coil—Single-phase Primary
B—Flux Interlinking with Secondary Coil—Polyphase Primary

of two-speed motors when the primary connections for the low speeds were established while the motor was still running at high speed. In closing the primary circuit, two contacts will always close first, in view of the practical impossibility of closing

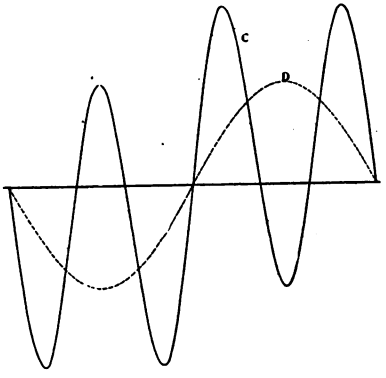


Fig. 16 b

C—Voltage in Secondary with Single-phase Primary
D—Voltage in Secondary with Polyphase Primary

all contacts simultaneously. The motor is, therefore, temporarily running with single-phase stator excitation and double synchronous speed. It may be shown by a simple calculation that the flux in the secondary coils assumes, in this case, a shape similar to those shown in Figs. 16a and 16b, and

Digitized by Google

17a and 17b, depending upon the phase position of the coils, and that voltages as shown in the same figures may be induced in the secondary coils. The dotted sine curves of the same figures show the double-speed secondary

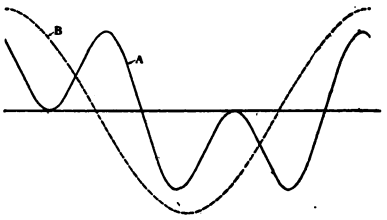


FIG. 17 A
A—FLUX INTERLINKING WITH SECONDARY COIL—SINGLE-PHASE PRIMARY
B—FLUX INTERLINKING WITH SECONDARY COIL—POLYPHASE PRIMARY

voltage induced by the polyphase field which is, of course, the same voltage as at standstill for which the insulation of the secondary circuits is usually designed. In other words, we obtain secondary voltages about twice as large as the normal voltage

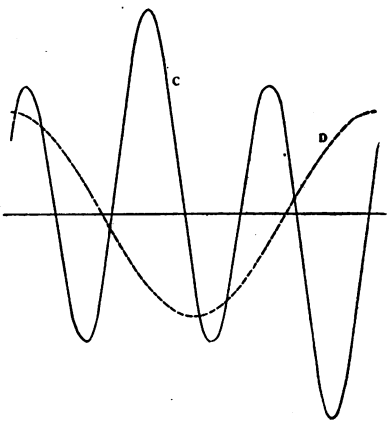


FIG. 17 B
C—VOLTAGE IN SECONDARY WITH SINGLE-PHASE PRIMARY
D—VOLTAGE IN SECONDARY WITH POLYPHASE PRIMARY

and it is either necessary to design the motors and control for this higher voltage or to avoid it by making arrangements so that the secondary is closed before the primary, which will, on account of the damping effect of the secondary, reduce the rate of change of the fluxes in the secondary coils and thereby the maximum

Digitized by Google

secondary voltages. Over-voltages are not only possible during the short period of single-phase excitation, but also exist at the moment when the third contact of a three-phase motor is closed, because this calls for sudden re-arrangement of the fluxes which may induce high voltage in the secondary. The voltage in the primary is, of course, always limited by the line voltage as soon as the primary switches are closed.

Conclusions

Other cases where transient conditions of induction machines are of practical importance with regard to the design of control arrangements might be cited, but it is considered that the discussion of the previous examples is sufficient to explain certain difficulties which have been experienced in practise and what points have to be watched in the design of the control, either in order to avoid bad effects by the transient conditions, or to call upon the same conditions for the purpose of avoiding certain other difficulties. As has been repeatedly pointed out, allowance should be made in this connection for the size of machine to be controlled, its inherent characteristics, and the like, as it is possible to take certain risks along the lines discussed in case of small low-voltage motors, while all the points may have to be considered very carefully in connection with other motors, for instance, of large capacity and high-voltage windings.

While practical experiences have taught both control and motor designers, relatively early, to take care of most of the conditions pointed out in this paper, it is believed that a more detailed study of the conditions to be met will lead to further improvements. The induction motor enjoys the just reputation of being the simplest motor requiring the least attention and maintenance of any of the existing motor types, and there is no doubt but that this reputation can only be improved if all characteristics of the motor are more fully understood and always properly taken care of by a harmonious combination of motor and control design.

Digitized by Google

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 16, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

PERFORMANCE OF POLYPHASE INDUCTION MOTORS, UNDER UNBALANCED SECONDARY CONDITIONS

BY A. A. GAZDA

ABSTRACT OF PAPER

Continuous operation of the wound-rotor induction motor, when the external resistances in the secondary phases are not equal, is shown to be feasible. The effect upon power factor and heating is discussed. Curves showing the performance of polyphase motors with single-phase secondary are presented. The practical advantages of using unbalanced secondary connections are pointed out.

DURING the past few years, the electrical engineer has been obliged to utilize every possible expedient in order to meet the demand for control apparatus having the fewest number of parts, and simplest connections. It was with this thought, that the following study of the operation of the polyphase induction motor, with unbalanced secondary, was made. No attempt will be made to present a complete mathematical discussion of all the phenomena taking place, but rather, to give a simple explanation of the effect upon the various characteristics, and show the feasibility of continuous operation when the secondary resistance is not equal in all phases.

In order to make the investigation thoroughly practical, a series of tests was made, to cover the following points:

1. The comparative heating of various motors when operated at a constant-torque load, with (*a*) balanced secondary, (*b*) unbalanced secondary, (*c*) single-phase secondary.

2. The effect upon primary and secondary current, power factor and torque, when the secondary is unbalanced.

3. The operating characteristics of a polyphase induction motor, with single-phase secondary.

The usual method of obtaining speed control of induction motors is to vary the secondary resistance. This may be done internally in various ways, but the more common practise is to use a phase-wound secondary with slip rings, whereby external

Manuscript of this paper was received December 27, 1916.

Digitized by Google

resistance may be inserted in the rotor circuit. This external resistance may be short-circuited in several steps by means of a controller, shown schematically in Fig. 1 A.

Referring to Fig. 1 B, it is evident that, although six switches are used, the resistance will be balanced on only three points, viz., No's 1, 4 and 7.

It has frequently been suggested that the unbalanced points be used for continuous running, but the objections were immediately raised that the secondary currents would be greatly unbalanced, and the heating increased to a prohibitive degree. This view seems logical at first glance, but further analysis shows that it is not justifiable, as there are several other factors to be taken into consideration. These will be discussed in turn.

I. The unbalancing of the secondary currents is not as great as the unbalancing of resistance would indicate. Some vector diagrams, showing typical conditions, will make this

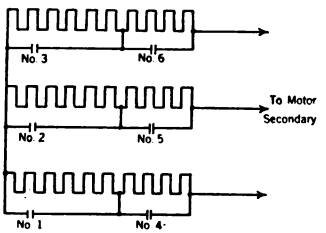


FIG. 1 A

SW.	RUN					
1	o	o	o	o	o	o
2		o	o	o	o	o
3			o	o	o	o
4				o	o	o
5					o	o
6						o

FIG. 1 B—SEQUENCE OF SWITCHES

clear. Take first the case in which a part of the resistance in one phase is short-circuited. (See Fig. 2). For the sake of simplicity, we will neglect the inductance and resistance of the secondary winding. The former would distort the diagram in such a way as to give a slightly greater difference between the low current and high current, while the latter merely adds a constant value to all phases which tends to balance the currents. It is seen that, although the resistance in one phase is only one-half the value in the other two, the difference between the maximum and minimum current is only 30 per cent. This does not mean that the one phase will carry an overload of 30 per cent., because, under balanced conditions, full-load current would take some intermediate value.

Fig. 3 is similar to Fig. 2, except that now two legs have low resistance, and one high. In this case, the ratio of maximum to minimum current is greater than before. Notwithstanding

Digitized by Google

this, the per cent above normal full-load current is less than in Fig. 2, because two phases are carrying the high current. Another way of looking at this is to say that in all cases, the currents adjust themselves so that the average r.m.s. value of the three currents is approximately equal to the normal balanced full-load current. In Fig. 2, the normal balanced current would

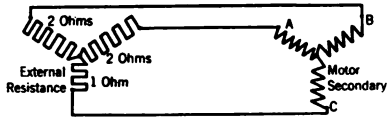


FIG. 2 A

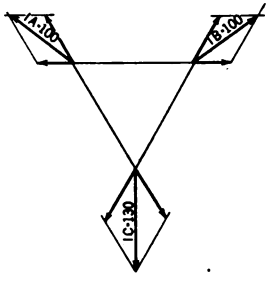


FIG. 2 B

be 111 amperes, and the overload in the maximum phase 17.1 per cent. In Fig. 3, the normal balanced current would be 135 amperes and the overload 11.1 per cent.

II. The unbalanced secondary currents react upon the primary in such a way as to draw a current from the line at a frequency which is lower than normal line frequency. This

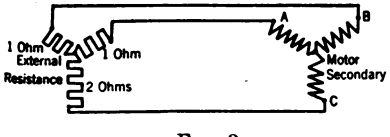


FIG. 3 A

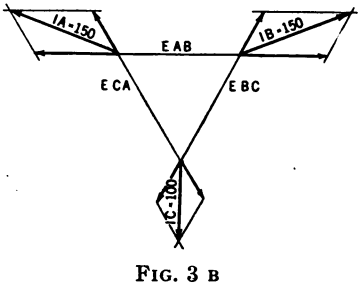


FIG. 3 B

phenomenon is caused by the single-phase component of the secondary field, the effect of which, in the extreme case of infinite resistance in one phase, has been explained by Mr. B. G. Lamme.[1] Fig. 4 is an oscillogram, showing this action in the case of a polyphase motor with a single-phase secondary, the motor running at half speed under this condition. Fig. 5 shows the

1. *Electric Journal*, Vol. XIII, page 394.

Digitized by Google

corresponding action when the secondary resistance is unbalanced.

The magnitude of this low-frequency current ranges from 10 to 30 per cent of the reactive component of full-load primary current, but it does not materially affect the primary line current, or the power factor of the motor. In the first place, any currents having a frequency different from that of the line voltage, are reactive, *i.e.*, they draw no power from the line[2]. Secondly, currents of different frequencies cannot be combined algebraically.

It was shown by Bedell and Tuttle,[3] that in such a case, in order to give a vectorial representation, the third dimension must be used. Referring to Fig. 6, E represents line voltage and

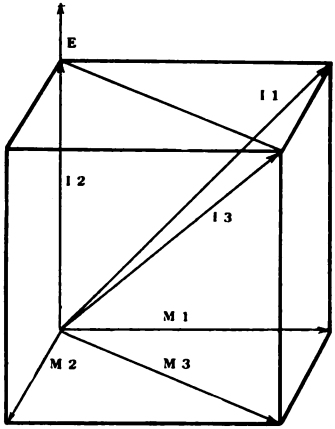


FIG. 6

I_1, the current that would flow if no harmonics were present. I_2 then, is the power component, and M_1, the magnetizing, or reactive component. The low-frequency current, due to the unbalanced rotor, may now be represented by M_2 at right angles to both E and M_1, while the resultant magnetizing current will be $\sqrt{M_1^2 + M_2^2}$ or M_3. Finally, the resultant current drawn from the line is $\sqrt{I_2^2 + M_3^2}$ or I_3. Combining the two previous statements, it is seen that $I_3 =$

2. This follows from the fact that $\int_0^{\pi} (\sin mt \sin nt\, dt)$ vanishes except for the case where $m = n$.

3. TRANS. A. I. E. E., 1906., Vol. XXV., page 685.

Digitized by Google

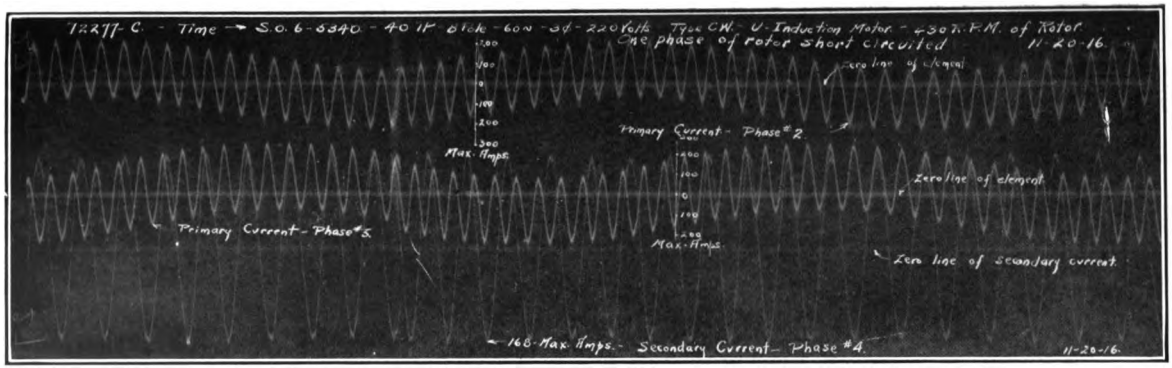
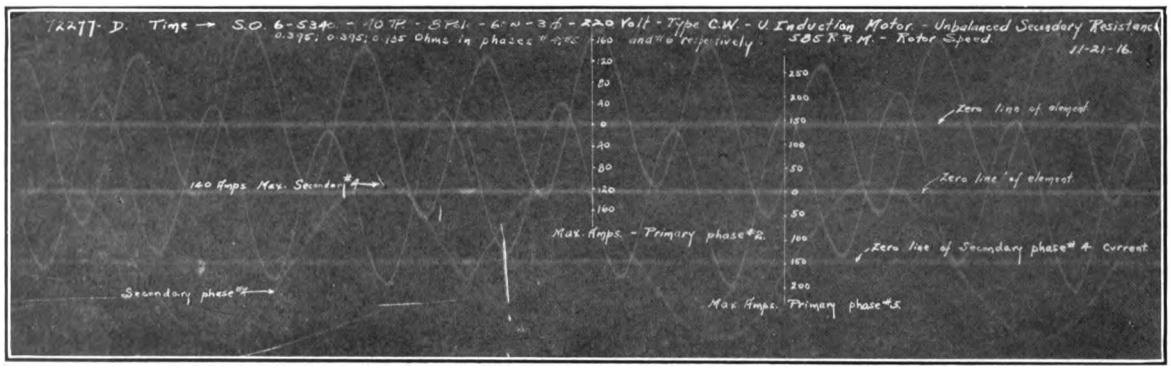

12277-C. - Time → S.O. 6-5340 - 40 ft. Block - 60 ~ - 3 ϕ - 220 Volts Type C.W. - U. Induction Motor - 1307 R.P.M. of Rotor
One phase of rotor Short Circuited
11-20-16.
Zero line of element
Primary Current - Phase #2.
Max. Amps.
Zero line of element
Primary Current - Phase #3.
Zero line of secondary current
168 Max. Amps. - Secondary Current - Phase #4.
11-20-16.

FIG. 4


12277-D. Time → S.O. 6-5340 - 40 ft. Block - 60 ~ - 3 ϕ - 220 Volt - Type C.W. - U. Induction Motor - Unbalanced Secondary Resistance
0.395; 0.395; 0.135 Ohms in phases #4, #3 and #2 respectively. 1285 R.P.M. - Rotor Speed.
11-21-16.
Zero line of element
140 Amps. Max. Secondary #4
Zero line of element
Max. Amps. - Primary phase #2.
Zero line of Secondary phase #4 current
Secondary phase #4
Max. Amps. Primary phase #3.

[GAZDA]

FIG. 5

Digitized by Google

corresponding action when the secondary resistance is unbalanced.

The magnitude of this low-frequency current ranges from 10 to 30 per cent of the reactive component of full-load primary current, but it does not materially affect the primary line current, or the power factor of the motor. In the first place, any currents having a frequency different from that of the line voltage, are reactive, *i.e.*, they draw no power from the line[2]. Secondly, currents of different frequencies cannot be combined algebraically.

It was shown by Bedell and Tuttle,[3] that in such a case, in order to give a vectorial representation, the third dimension must be used. Referring to Fig. 6, E represents line voltage and

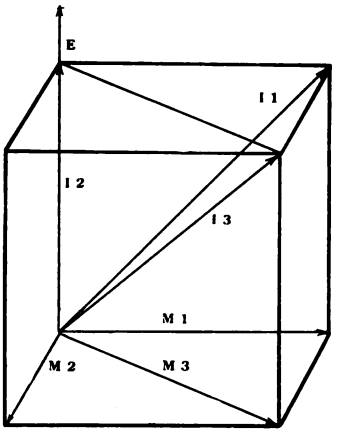


FIG. 6

I_1, the current that would flow if no harmonics were present. I_2 then, is the power component, and M_1, the magnetizing, or reactive component. The low-frequency current, due to the unbalanced rotor, may now be represented by M_2 at right angles to both E and M_1, while the resultant magnetizing current will be $\sqrt{M_1^2 + M_2^2}$ or M_3. Finally, the resultant current drawn from the line is $\sqrt{I_2^2 + M_3^2}$ or I_3. Combining the two previous statements, it is seen that $I_3 =$

2. This follows from the fact that $\int_0^{\pi} (\sin mt \sin nt\, dt)$ vanishes except for the case where $m = n$.

3. TRANS. A. I. E. E., 1906., Vol. XXV., page 685.

Digitized by Google

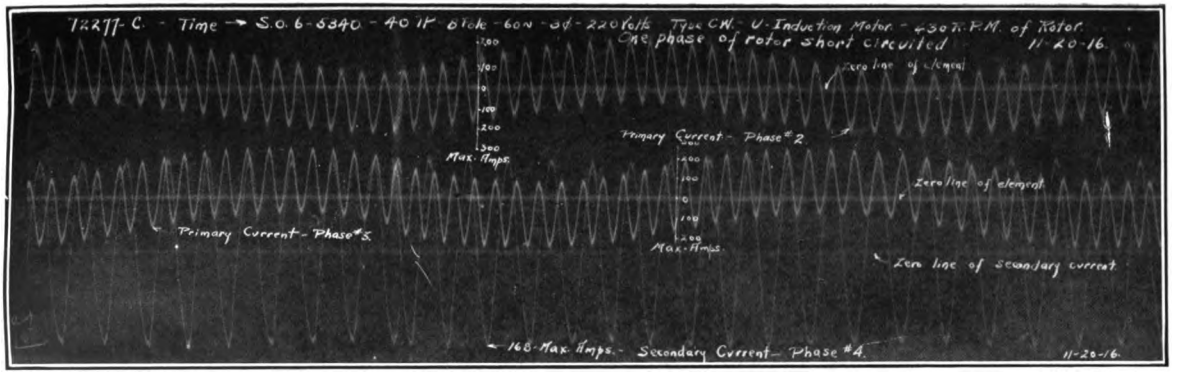
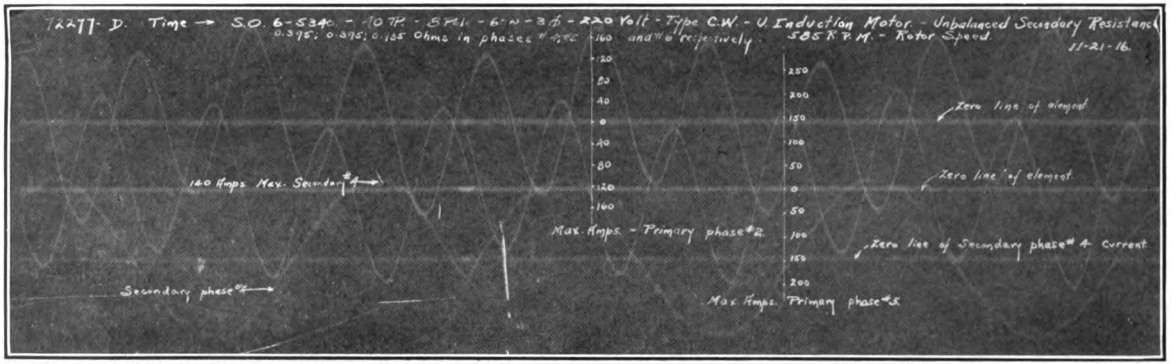

12277-C. - Time → S.O. 6-6340 - 40 ~ - 6 Pole - 60 ~ - 3 ϕ - 220 Volts Type C.W. - U Induction Motor. - 430 R.P.M. of Rotor.
One phase of rotor Short circuited
11-20-16.
Zero line of element
Primary Current - Phase #2
Max. Amps.
Zero line of element
Primary Current - Phase #3
Max. Amps.
Zero line of Secondary current
168 Max. Amps. - Secondary Current - Phase #4.
11-20-16.

FIG. 4


12277-D. Time → S.O. 6-5340 - 40 ~ - 3 Pole - 60 ~ - 3 ϕ - 220 Volt - Type C.W. - U Induction Motor. - Unbalanced Secondary Resistance
0.375, 0.395, 0.135 Ohms in phases #4 #5 and #6 respectively. 585 R.P.M. - Rotor Speed.
11-21-16.
Zero line of element
160 Amps. Max. Secondary #4 →
Zero line of element
Max. Amps. - Primary phase #2.
Zero line of Secondary phase #4 Current
Secondary phase #4 →
Max. Amps. Primary phase #3.

[GAZDA]

FIG. 5

Digitized by Google

Digitized by Google

$\sqrt{I_2 + M_1^2 + M_2^2}$. Hence, if M_2 is as high as 30 per cent of M_1, M_3 will be only 4.5 per cent greater than M_1, which means that the increase in the reactive component, due to unbalancing, will not exceed 5 per cent. Assuming that a motor runs normally at a power factor of 80 per cent, unbalancing the rotor resistance will decrease this value to 78.6 per cent. On the other hand, the increase in line current will be 1.5 per cent under the same condition, and hence, primary copper heating will be 3 per cent greater than under balanced conditions. Since the primary draws just sufficient low-frequency magnetizing current to compensate for the pulsating action of the secondary, the flux conditions remain the same as in the case of a balanced rotor, and the iron losses are not changed.

III. The rating of a variable speed motor depends upon the heating at the lowest running speed, because ventilation is poorest at this speed. Since the fan action of the rotor varies approximately as the square of the speed, the least ventilation will occur on the first notch of the controller, which, in commercial practise, usually connects all the external resistance to the secondary circuit, in a balanced arrangement. Even though succeeding steps cut out the resistance in such a way that unbalanced conditions are obtained, the ventilation is improved so much by the higher speed, that the motor will dissipate considerably more heat, with the same temperature rise, and the rating is not diminished by the slightly increased losses.

IV. As was pointed out in Part I, the currents will not be the same in all phases of the secondary. However, it is not correct to assume that the rating will be limited by the maximum current in any phase. Experience shows that in any rotating apparatus carrying unbalanced load, the heating, broadly speaking, will be proportional to the sum of the squares of the various currents ($I_1^2 + I_2^2 + I_3^2$). This is particularly true of rotor windings. The design limitations will have a bearing on this factor; for instance, if the coils are heavily wrapped with insulation, localized heating may take place. This rarely occurs, because the designer may choose comparatively low voltage for the secondary, since it is independent of power supply. Furthermore, modern mica-insulated coils conduct the heat out of the copper very readily.

V. A large number of tests were made on motors of various sizes, speeds, etc., to check the foregoing conclusions. In the

Digitized by Google

TABLE I—OPERATION OF 40-H.P., 3-PHASE, 60~, 220-VOLT INDUCTION MOTOR WITH VARIOUS VALUES OF EXTERNAL SECONDARY RESISTANCE.

Resistance in ohms per leg			Primary Volts			Primary Amps.			Equivalent Balanced Pri. Amps. (R.M.S.)	Secondary Amps.			Equivalent Balanced Sec. Amps. (r.m.s.)	Speed in r.p.m.	Pound Feet Torque	Power Factor
0.81	0.81	0.81	220	218	220	114.8	109.2	110.8	111.8	77.2	76.8	76	76.7	415	242	78.6
0.81	0.81	0 39	220	218	220	117.7	110	114	114	64.4	90.1	79.2	78.6	520	242	77.15
0.39	0.39	0.81	220	218	220	117	110	114	113.8	90.6	62.3	79.5	78.4	600	242	77.5
0.39	0.39	0.39	220	218	220	111.7	104	110	108.7	75.2	75.2	74.8	75.15	660	242	79.7
0.13	0.13	0 39	220	218	220	114	108	112	111.4	90.7	55.4	81.7	77.2	768	242	78.4
0.39	0.39	0.13	220	218	220	114	108	111	111.2	63	92.6	72.4	77.1	723	242	78.2

Digitized by Google

load runs, particular attention was paid to the rotor copper, to detect any temperature rises greater than normal. The uniform heating of the rotor was demonstrated by both thermometer and resistance readings. The total secondary copper loss was found to run 5 to 10 per cent higher under unbalanced than under balanced conditions. This bears out the statement that $I_1^2 + I_2^2 + I_3^2 = 3\,I_n^2$, where I_1, I_2 and I_3 represent the unbalanced currents, while I_n is the normal balanced current. (See Table I.) In a series of load runs with constant torque, using a controller which gave unbalanced points, it was found that the temperature rise, with the first one or two steps of

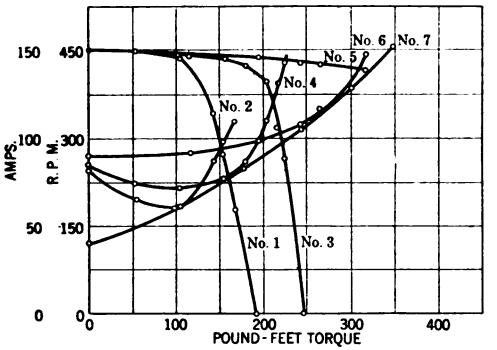


FIG. 7—FORTY-H. P., THREE-PHASE, 60-CYCLE, 220-VOLT, 8-POLE INDUCTION MOTOR—SINGLE-PHASE ROTOR

Curve 1—Speed—torque—1.6 ohms resistance in one phase of rotor
Curve 2—Primary amperes—torque—1.6 ohms resistance in one phase of rotor
Curve 3—Speed—torque—0.8 ohms resistance in one phase of rotor
Curve 4—Primary amperes—torque—0.8 ohms resistance in one phase of rotor
Curve 5—Speed—torque—one phase of rotor short-circuited
Curve 6—Primary amperes—torque—one phase of rotor short-circuited
Curve 7—Primary amperes—torque—three phases of rotor short-circuited

resistance cut out, was the same as on the first balanced point, while at still higher speeds, the rise was less, even though the secondary was unbalanced. Test fully justified the statements made in Part II, in regard to primary current and power factor. Very accurate readings had to be taken in order to check the small increase in current. Although it was found that the degree of unbalancing had some effect on the operation of the motor, nevertheless, with the unbalancing that is common in standard commercial controllers, the operating characteristics are well within the limits stated previously. The per cent of no-load magnetizing current in terms of full-load current, had a distinct influence upon the increase in primary and secondary currents.

Digitized by Google

In general, the motors with small no-load magnetizing current, showed the best performance.

Tests were made to observe the operation of polyphase motors running with single-phase secondary. Under these conditions, the starting torque was found to be about 60 per cent of the torque with balanced conditions, the current in the secondary winding being the same in each case. With this connection, an economical method of continuous operation at half speed is obtained. An important advantage of this method is that a stable speed is maintained, independent of the load. This would mean a great saving in resistors, particularly where half speed is desired at reduced torque, as in fan or centrifugal

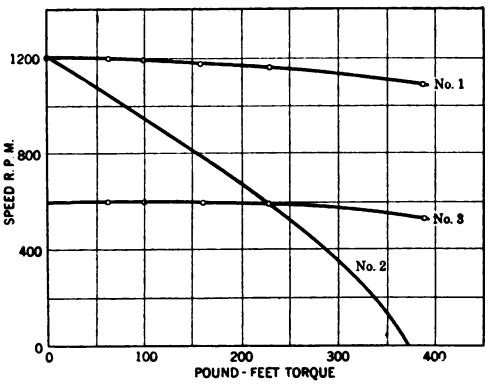


FIG. 8 A—TORQUE CHARACTERISTICS OF 50-H. P., THREE-PHASE, 60-CYCLE, 220-VOLT, 6-POLE INDUCTION MOTOR

Curve 1—Speed—torque—short-circuited rotor
Curve 2—Speed—torque—balanced secondary resistance
Curve 3—Speed—torque—single-phase rotor

pump application. The no-load magnetizing current is a very important factor in this case, and must be taken into account. For example, small low-speed motors may draw excessive currents with one phase of the secondary short-circuited, or if too much external resistance is inserted in the single-phase secondary, a stable condition will not be obtained at half speed. Fig. 7 shows the torque and current characteristics of a 40-h.p., 3-phase, 60-cycle, 8-pole, 220-volt induction motor, with wound secondary, when one phase of the secondary is open-circuited. These curves are plotted from test results, and perhaps are the first to show the effect of secondary resistance, under the given conditions. At no load the primary magnetizing current is approximately twice the amount required under normal bal-

Digitized by Google

anced conditions, but as the load increases, an apparent paradox takes place, in that the line current decreases to a certain minimum value before any increase takes place.

Curves in Fig. 8A and 8B show comparative characteristics of a 50-h.p. motor, (1) when operating with single-phase secondary, (2) when operating with 3-phase balanced resistance, to give half speed at full-load torque. The reduced power factor under the single-phase secondary condition is due to the great decrease in power drawn from the line, while the reactive com-

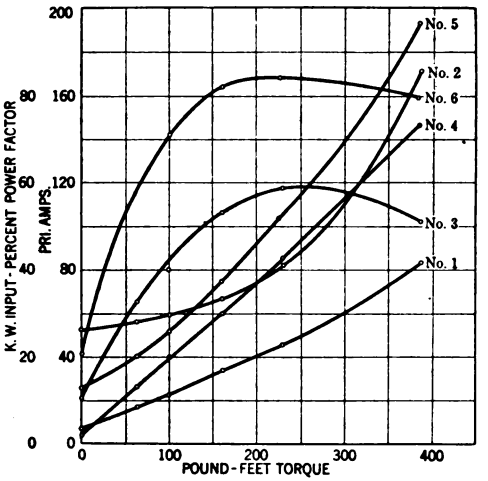


FIG. 8 B—TORQUE CHARACTERISTICS OF 50-H. P., THREE-PHASE, 60-CYCLE, 220-VOLT, 6-POLE INDUCTION MOTOR

Curve 1—Input—torque—single-phase rotor
Curve 2—Primary amperes—torque—single-phase rotor
Curve 3—Power factor—torque—single-phase rotor
Curve 4—Input—torque—polyphase rotor
Curve 5—Primary amperes—torque—polyphase rotor
Curve 6—Power factor—torque—polyphase rotor

ponent remains practically constant. Note that at full-load torque, the power input required is reduced almost 50 per cent. These curves show that it is quite possible to obtain a half-speed running point by this method.

CONCLUSION

The practical significance of this investigation may be summarized as follows:

1. With the proper design of resistor steps, it is safe practise to operate polyphase induction motors at full-load torque, with

Digitized by Google

unbalanced secondary resistance. Under these conditions, the power factor will be slightly reduced, but the increased copper loss will be amply compensated for by the better ventilation of the motor at the higher speeds.

2. A limited range of motors which have a low percentage of magnetizing current, may be operated under full-load torque at half speed, with single-phase secondary, while practically any motor may be operated under these conditions when connected to a variable torque load, such as blowers, centrifugal pumps, etc.

By taking advantage of the principles brought out in this paper, it will be possible to obtain much simpler control apparatus than has been common in the past. Control schemes, including single-pole resistance switches, may be used, which will result in fewer parts to maintain, less control wiring, and smaller size controller. The amount of resistance may be reduced, and floor space saved.

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers New York, February 16, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

INDUSTRIAL CONTROLLERS—WITH PARTICULAR REFERENCE TO THE CONTROL OF DIRECT-CURRENT SHUNT MOTORS

BY H. D. JAMES

ABSTRACT OF PAPER

Stating that present day development of motors and controllers is such that former limitations as to regulation of starting current from the viewpoint of motor, controller and supply system have been largely removed, the author presents a series of tests on 15 and 20-h.p., 230-volt, d-c. shunt motors, started from rest. The motors are of two types, constant and adjustable speed.

These tests were made to determine: first, the load driven by the motor; second, the power supply; third, the motor operation.

From these tests the author concludes, in part; that it is practical with automatic acceleration to use one switch to short-circuit the armature resistor used with motors as large as 15 h. p.; that the shunt field of small adjustable speed motors can be reduced in one step under normal load conditions (this practise can be safely followed up to motors of 50 h. p.); and that adjustable speed motors can use one step resistance for dynamic braking.

THE PRESENT practise in industrial control is the result of accumulated experience extending over the past twenty-five years. The theory consists in analyzing the characteristics of the motor to be controlled, and designing a controller which will furnish the characteristics not incorporated in the motor design. An analysis of the motor, from this standpoint, has brought out a number of features which were not generally appreciated.

The application of the controller requires an analysis of the load to be driven by the motor, as well as the characteristics of the motor. The controller must cause the motor to operate through a cycle which is best adapted to the motor load, or the machinery to which the motor is connected. The engineer must never lose sight of the fact that the purpose in using a motor and controller is to do certain work, and that he should select a type of motor and controller that will perform this work under existing conditions with the least apparatus, and require the minimum of attention.

Manuscript of this paper was received December 26, 1916.

Digitized by Google

In the early days of the d-c. motor, great care had to be taken in starting, and in changing the motor speed, to prevent bad sparking or flashing. This led to the practise of using a considerable number of steps in the external armature resistor, to give a small change in amperes per step. The most common form of motor starter, even today, is a face plate, the design lending itself readily to the use of a large number of steps. Furthermore, the characteristics of this starter are such that considerable burning would result if there were a large change in current per step, so that a relatively large number of steps are necessary to protect the starter against excessive wear.

The steady improvement in the design of motors and controllers has removed many of the limitations formerly existing. At one time the permissible starting current was seriously limited by the danger of disturbance to the supply voltage. The increase in the capacity of systems supplying power now permits small and medium size motors to start with twice full-load current, or even more, without disturbing the supply voltage. Many motor applications are made in factories and mills where there is a continual change in the power demand, so that the starting of relatively small motors makes little difference in the total load.

However, there still exists a number of applications where starting current is an important feature, such as elevators and some other apparatus used in public buildings. Printing presses, paper machinery and applications of similar nature, require special controllers to give a slow start to properly manipulate the product.

Direct-current series and compound motors, as large as 20 h.p. are in successful operation, without the use of an external starting resistor. Mr. Hansen, in his paper published elsewhere in this issue, shows oscillograph records illustrating the starting of these motors. Shunt motors as large as 15 h.p. connected to drum controllers, short-circuiting the starting resistor in one step, have been in successful operation for over ten years.

In order to get a better understanding of the conditions when a d-c. shunt motor is started from rest, the writer arranged for a number of tests on standard motors for general purposes, equipped with automatic starters. These tests were made to determine the effect upon:

First, the load driven by the motor.
Second, the power supply.
Third, the motor operation.

Digitized by Google

No tests were made upon the controller itself, as commercial controllers are now available which are well able to meet all service requirements. A magnetic contactor controller, of modern design, should be able to take care of any starting conditions which can be met by the motor, without causing undue wear upon any part of the controller.

Most d-c. shunt motors, designed for general purposes, start with less than full load, so that the tests were made with different methods of loading.

The controller was adjusted to short-circuit the starting resistor, while the counter e.m.f. of the motor was quite low. The starting current was also kept small in order to exaggerate the starting conditions. The armature voltage at which the resistance was closed can readily be seen by the notch in the counter e.m.f. curve.

This investigation covered only small motors, as these are typical of most of the motors used, and cover a field where very little application engineering work can be done. It is very desirable to have a simple and strong controller for these motors, as they are often used where the operating conditions are bad and expert attention is not given them. The application of larger motors frequently requires the investigation of the load conditions by engineers, who can specify the correct motor and controller, and modify the controller to adapt it to any special requirements, if desirable. Furthermore, large motors usually receive better care.

Apparatus Used in Making Test.—An oscillograph was employed in all these tests. Figs. 2 to 14 for the 20-h.p. motors were taken on a cylinder, giving the total time of approximately two seconds. Figs. 15 to 21 for the 15-h.p. motor were taken on a long film attachment, and the time for these curves was four to six seconds.

In all cases, the motors used were standard 230-volt shunt-wound d-c. motors. The voltage at the supply circuit dropped a little below this value, and varied from 220 to 225 volts.

The load, in all but two cases, consisted of a d-c. generator, slightly larger in size than the motor, belted to the motor. The generator exerted no retarding force, other than that due to friction and inertia, except where noted. This will represent the majority of loads which a motor of this class will be called upon to start. In one case, the field of the generator was excited, and the armature short-circuited through sufficient resistance

Digitized by Google

to develop full motor torque at full speed. This condition more nearly represents the starting of a heavy fan, or centrifugal pump.

The tests on all 20-h.p. motors were made with an automatic controller having a wiring diagram shown in Fig. 1. The switches used on this controller were standard type *C* contactors, of 125-ampere capacity. The first resistance switch was of the series lock-out type, and the second switch of the counter e.m.f. type. Where the resistance was cut out in one step, the first switch was blocked in the open position.

For the adjustable speed motors, a series relay was used to short-circuit the field resistor during acceleration. This relay was open when the armature resistor was short-circuited, and

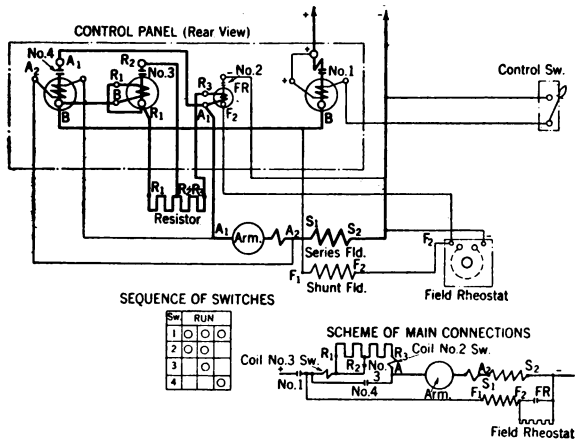


FIG. 1—DIAGRAM OF CONNECTIONS

allowed the field to decrease to its minimum value. When the motor was at rest, the shunt-field strength was either zero or equal to that for the maximum speed condition. The constant speed shunt motor had its field disconnected in the off position, in all of the tests. For the internal resistance of the motors and controller see the curves and diagrams.

Tests on 20-*h. p.*, 750-*rev. per min.*, 230-*Volt, d-c., Shunt Motor.* See Fig. 22. Fig. 2 shows the motor started with 1.35 ohms external armature resistance, which was reduced to 0.35 of an ohm when the counter e.m.f. equalled 120 volts. The second step of resistance was short-circuited when the counter e.m.f. reached 160 volts. This is a very good record of a two-step automatic starter.

Digitized by Google

Fig. 3 shows the same motor, with one ohm external armature resistance. The entire resistance in this case was short-circuited in one step. The resistance switch was not

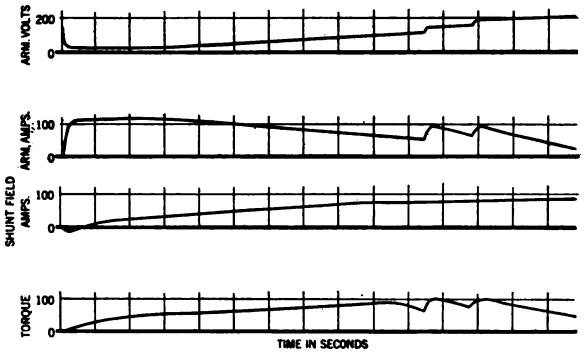


FIG. 2—20-H. P. MOTOR—750 REV. PER MIN.—TWO-STEP STARTING RESISTANCE 1.35 OHMS

closed until the counter e.m.f. of the motor equalled 190 volts. This represents an adjustment which is better than can usually be obtained in practise.

Fig. 4 shows the motor started with 1.35 ohms external re-

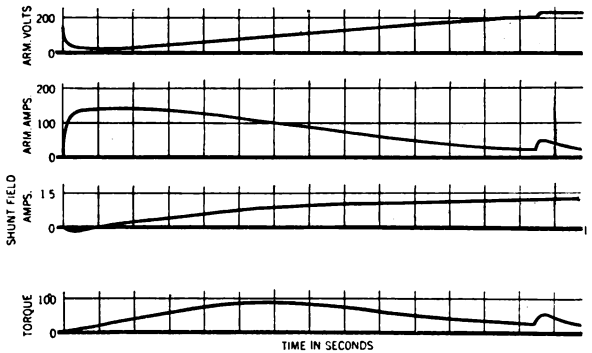


FIG. 3—20-H. P. MOTOR—750 REV PER MIN.—ONE-STEP STARTING RESISTANCE 1.00 OHM

sistance, the resistance being short-circuited in one step, the switch closing when the counter e.m.f. of the motor was 150 volts. This adjustment gives equal current peaks, and represents a practical controller.

Digitized by Google

Fig. 5 shows a start under the same conditions as Fig. 4, except that the short-circuiting switch closed at 120 volts. This shows a peak at the time of short-circuiting the armature resistance, in excess of the starting current, and represents very

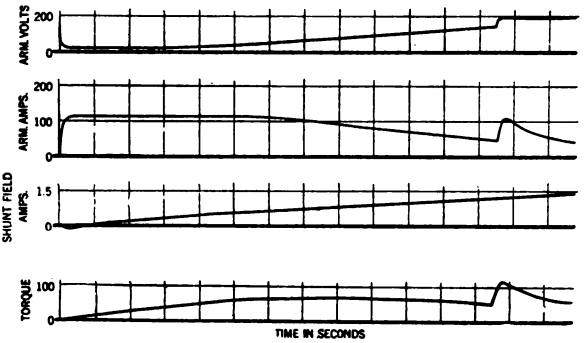


FIG. 4—20-H. P. MOTOR—750 REV. PER MIN.—ONE-STEP STARTING RESISTANCE 1.35 OHMS

bad commercial practise. Figs. 3, 4 and 5 show very clearly the results obtained when the short-circuiting switch closes at different values of counter e.m.f.

Fig. 6 shows a one-step start, with one ohm external armature

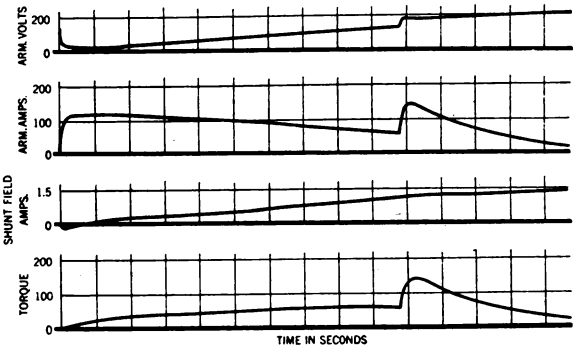


FIG. 5—20-H. P. MOTOR—750 REV. PER MIN.—ONE-STEP STARTING RESISTANCE 1.35 OHMS

resistance, the short-circuiting switch closing at about 125 volts, counter e.m.f. This curve has the same adjustment for short-circuiting the armature resistance as Fig. 5, and shows that the current peaks can be made approximately the same by increasing the initial current.

Digitized by Google

Fig. 7 shows a start with 0.765 of an ohm external armature resistance, with one short-circuiting switch. The load on the motor, in this case, was a prony brake, set to give full load torque. This represents a very difficult starting condition, as the

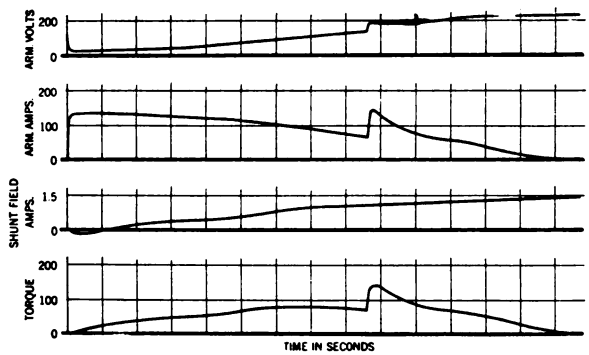


FIG. 6—20-H. P. MOTOR—750 REV. PER MIN.—ONE-STEP STARTING RESISTANCE 1.00 OHM

static friction of the brake is considerably in excess of full load torque. The start, however, was successfully made with one step of resistance.

In the curves referred to, armature volts, armature amperes

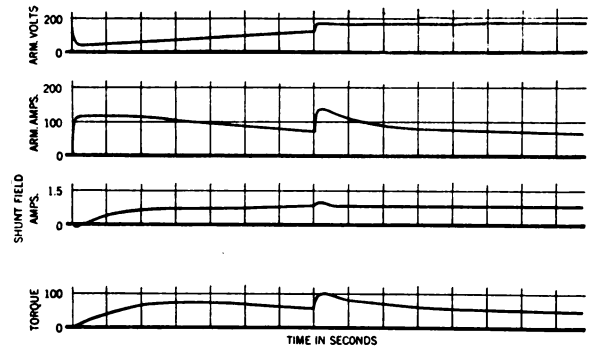


FIG. 7—20-H. P. MOTOR—700 REV. PER MIN. FULL LOAD—ONE-STEP STARTING RESISTANCE 0.725 OHM

and shunt field amperes were taken from the oscillograph records. The torque curve was plotted by assuming that the field flux was proportional to the shunt field amperes, except that the negative value of the shunt-field current, at starting,

Digitized by Google

was neglected, and the torque curve started at zero value. While these assumptions are not strictly correct, they serve to show the characteristic shape of the torque curve. Since the motor was connected to the line with zero field current, it can be assumed that the initial torque was approximately zero, and independent of the armature current. This torque shows a gradual increase, the armature current remaining constant for a brief period, until sufficient torque is developed to start rotation. Fig. 3 shows how this torque not only increased gradually, but decreased again, up to the point of short-circuiting the armature resistance. At this instant, the torque has a momentary increase, and again tapers off. Some of the curves show a slight change in the field current at this instant, due to the transformer action between the armature current and the field windings. This momentary change in field current was neglected in plotting the torque curve, as it was assumed that the field flux would show an opposite change.

I wish to lay special emphasis upon the characteristic shape of this torque curve, at the time of starting the motor from rest. This curve shows that the motor will start its load gradually, independent of the value of armature current. A heavy armature current, several times the value of full-load current, can be used with safety, providing there is no serious effect on the voltage of the supply circuit, which might be objectionable for other reasons. An easy start of the load is very desirable, as there usually is considerable lost motion in the gearing, or other mechanical connections, between the motor and its load. The sudden application of torque would cause a hammer blow, and might injure the machinery. The sudden increase in torque, at the time the section of the armature resistance is short-circuited, is not so dangerous, as long as a positive torque is maintained, and there is no lost motion in the machinery. Figs. 2 and 4 show that very little improvement can be made by using two switches to short-circuit the starting resistor.

Tests on a 20-*h. p., Adjustable Speed,* 230-*Volt, D-C., Shunt Motor, Having Speed Adjustment of* 500 *to* 1500 *rev. per min.* (*See Figs.* 23 *and* 24) These tests are duplicates of the previous ones, except that, in some cases, the shunt-field current has an initial value equal to the value when the motor is operating at 1500 rev. per min. Also, the field resistance, at the instant of starting the motor, is short-circuited, and again open-circuited at the instant of short-circuiting all of the external resistance.

Digitized by Google

Fig. 8 shows a typical start, short-circuiting the external armature resistance in two steps, the initial resistance being one ohm, and the resistance of the last step 0.25 of an ohm.

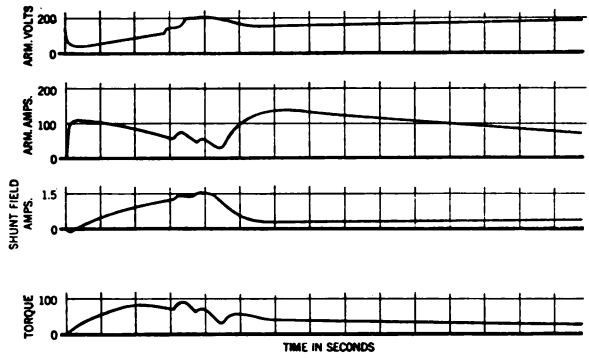


FIG. 8—20-H. P. MOTOR—500-1500 REV. PER MIN. FULL LOAD—TWO-STEP STARTING RESISTANCE 1.00 OHM

The first switch closed at approximately 125 volts and the second switch at 175 volts, counter e.m.f. It is evident, from this curve, that the second step of starting resistance was not necessary.

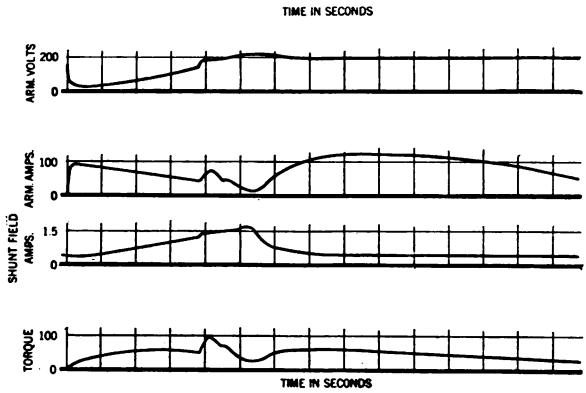


FIG. 9—20-H. P. MOTOR— 500-1500 REV. PER MIN.—TWO-STEP STARTING RESISTANCE 1.50 OHMS

Fig. 9 shows a similar two-point starter, having an initial resistance of 1.5 ohms, the second step of resistance being 0.25 of an ohm.

Figs. 10 and 11 show similar starts, with 0.765 ohms external

Digitized by Google

resistance. In these two tests the armature resistance is short-circuited in one step.

Fig. 12 shows a single-step start, with the same amount of

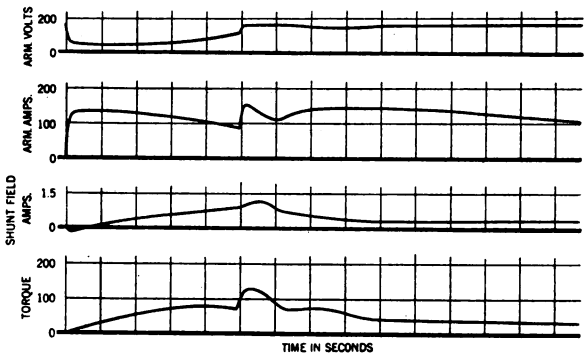


FIG. 10—20-H. P. MOTOR—500-1500 REV. PER MIN.—ONE-STEP STARTING RESISTANCE 0.765 OHMS

armature resistance 0.765 ohms), but with the generator loaded, so that it developed full-load torque, at full speed.

Fig. 13 shows a start under similar conditions, except that the motor was loaded with a prony brake, giving full-load torque.

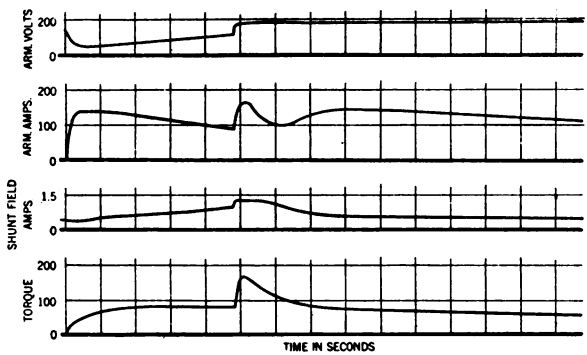


FIG. 11—20-H. P. MOTOR—500-1500 REV. PER MIN.—ONE-STEP STARTING —RESISTANCE 0.765 OHMS

Fig. 14 shows a single-step start, having an armature resistance of 1.5 ohms, the short-circuiting switch closing at about 140 volts, counter e.m.f., giving equal starting and short-circuiting current peaks.

Digitized by Google

These curves differ from the preceding set in characteristic shape, after the armature resistance has been short-circuited. This is due to a gradual decrease in the shunt field strength, with a corresponding increase in the armature current. This

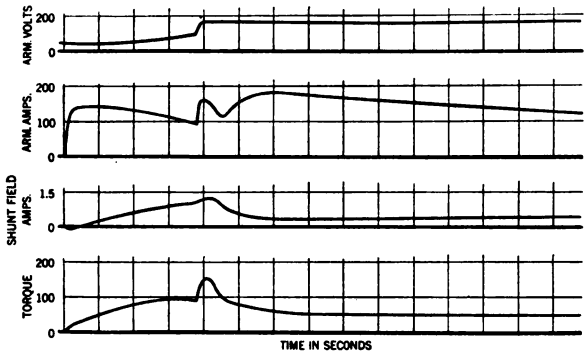


FIG. 12—20-H. P. MOTOR—500-1500 REV. PER MIN. FULL LOAD—ONE-STEP STARTING RESISTANCE 0.76 OHM

change in field strength and current is gradual, and it does not seem necessary to use automatic means for delaying this change in field strength.

Different methods of loading the motor do now show much

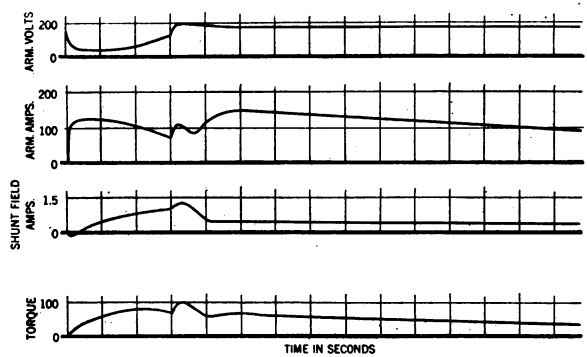


FIG. 13—20-H. P. MOTOR—500-1500 REV. PER MIN. FULL LOAD—ONE-STEP STARTING RESISTANCE 0.765 OHMS

change in the current peak when the resistance is short-circuited. This is largely dependent upon the value of the counter e.m.f. at the time of short-circuiting the starting resistance. In none of the tests was this peak excessive.

Digitized by Google

Tests on a 15-*h.p.*, 230-*Volt*, 400 *to* 1600 *rev. per min.*, *D-C.*, *Shunt Motor.* (*See Figs.* 25 *and* 26). A number of tests were made on this motor, using a controller connected as shown in Fig. 27. In these tests the motor was belted to a generator a

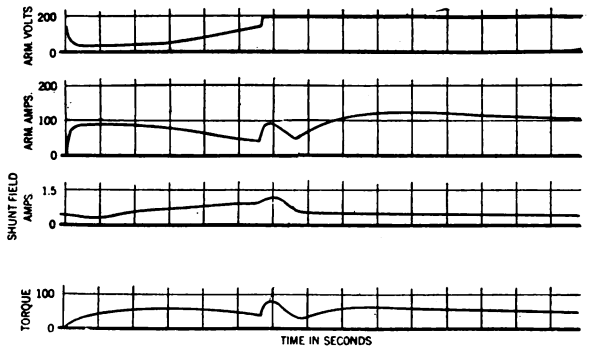


FIG. 14—20-H. P. MOTOR—500-1500 REV. PER MIN.—ONE-STEP STARTING RESISTANCE 1.5 OHMS

little larger than the motor. The only load to be overcome was that due to friction and inertia.

The controller differs from that shown in Fig. 1 in the connections to the shunt field relay. In this case a "fluttering" or

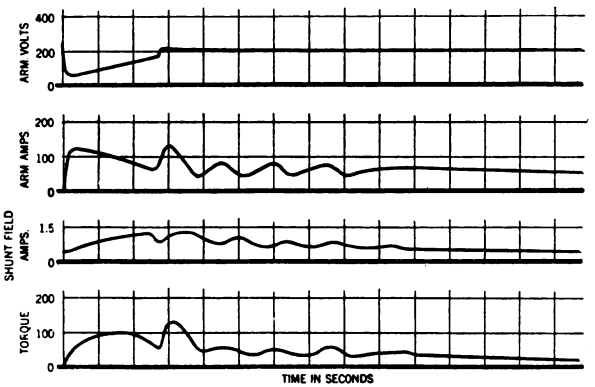


FIG. 15—15-H. P. MOTOR—400-1600 REV. PER MIN.

"vibrating" relay was substituted for the series switch. Provision is made for keeping these relay contacts closed during acceleration, by using more ampere turns on the relay during this period. (See Fig. 27.)

Digitized by Google

This fluttering relay is arranged to close its contacts when the current exceeds a fixed value, and to open the contacts when the current is reduced below this value. The difference between the closing and opening values of current is about 10 per cent.

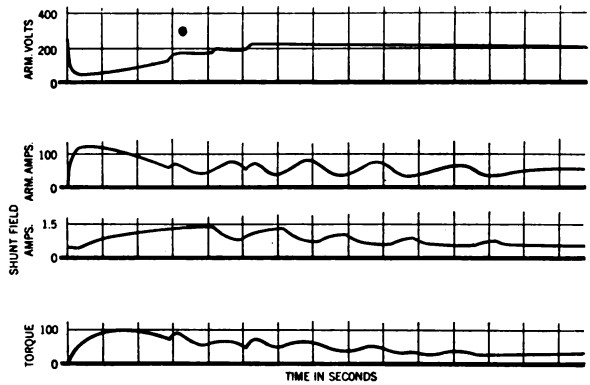


FIG. 16—15-H. P. MOTOR—400-1600 REV. PER MIN.

The object of the relay is to control the weakening of the shunt field during the period of acceleration from 400 rev. per min. to a higher speed, depending upon the setting of the field rheostat. It operates in a similar manner to a voltage regulator. The

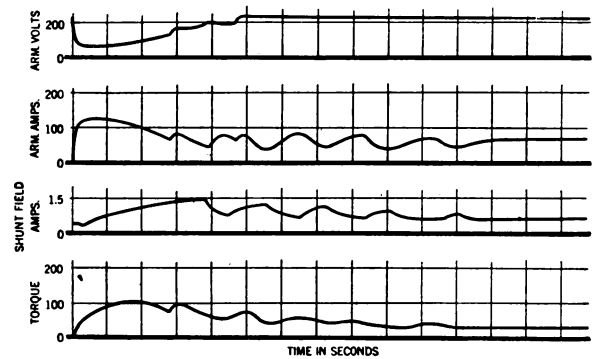


FIG. 17—15-H. P. MOTOR—400-1600 REV. PER MIN.

relay contacts short-circuit the field rheostat, the rapid cutting in and out of the field rheostat tending to retard the weakening of the shunt field.

Tests shown by Figs. 15, 16 and 17 indicate that the action of such a relay is not very smooth. When this principle is

Digitized by Google

applied to the exciter of a large d-c. generator, the pulsations are damped out to a considerably greater extent. Moreover, the parts of the voltage regulator are lighter and the regulator is much quicker in its operation and much more sensitive to a change in current.

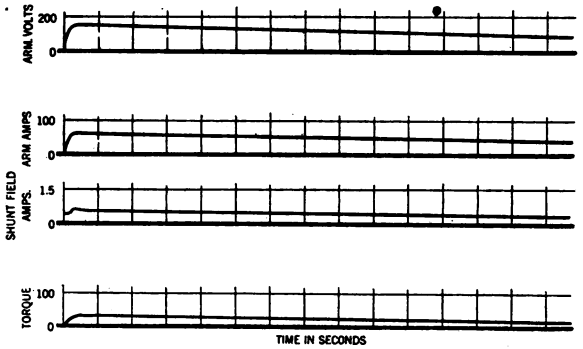


FIG. 18—15-H. P. MOTOR—400-1600 REV. PER MIN.

By comparing these curves with the preceding curves, made on a three-to-one adjustable speed motor, it will be seen that the armature current and torque are considerably more disturbed when the relay is used, than in the cases where this relay

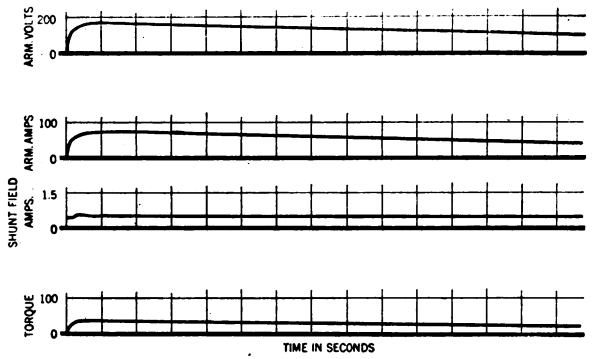


FIG. 19—15-H. P. MOTOR—400-1600 REV. PER MIN.

is omitted. It would, therefore, seem unwise to add this complication to the average small motor.

There is another objection to the use of this relay. If we consider the above motor operating at 1600 rev. per min., and quickly move the field rheostat to reduce the motor speed to

Digitized by Google

1200 rev. per min., the motor will regenerate and cause a heavy reverse current to flow. This excess current will lift the fluttering relay and short-circuit the field rheostat. This action still further increases the field strength of the motor and causes an

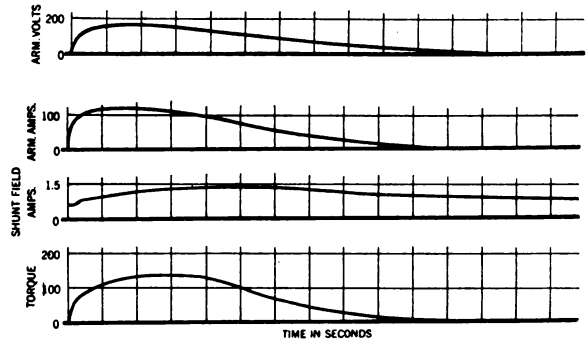


FIG. 20—15-H. P. MOTOR—400-1600 REV. PER MIN.

increase in the armature current. The action of the relay in this case is the reverse of its operation during acceleration, and has a very undesirable effect.

In order to correct this difficulty, a second relay known as a

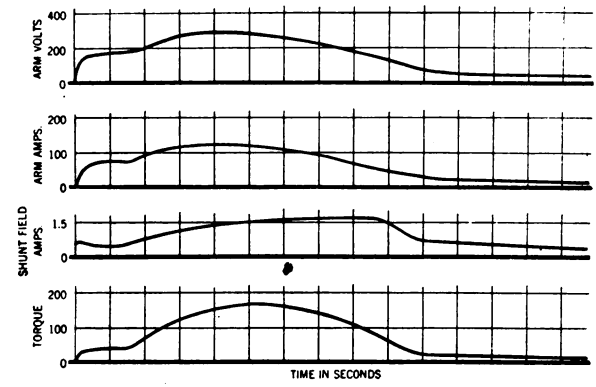


FIG. 21—15-H. P. MOTOR—400-1600 REV. PER MIN.

"transfer" relay has been used. This relay has a compound winding so arranged that it reverses the connections to the fluttering relay when the motor regenerates. In order to properly protect the motor it is, therefore, necessary to use two relays instead of one. Controllers for paper calenders, printing presses

Digitized by Google

and other applications having motor-operated field rheostats, can use the fluttering relay without a transfer relay, as the movement of the field rheostat is slow.

Dynamic Braking. This same 15-h.p. four-to-one adjustable speed motor was arranged for dynamic braking. The connections were such that the field rheostat could be short-circuited during the period of braking. Figs. 18 and 19 show the braking characteristics with the field strength remaining constant and the motor operating at 1600 rev. per min. when the dynamic brake was applied. The drift in this case was considerable,

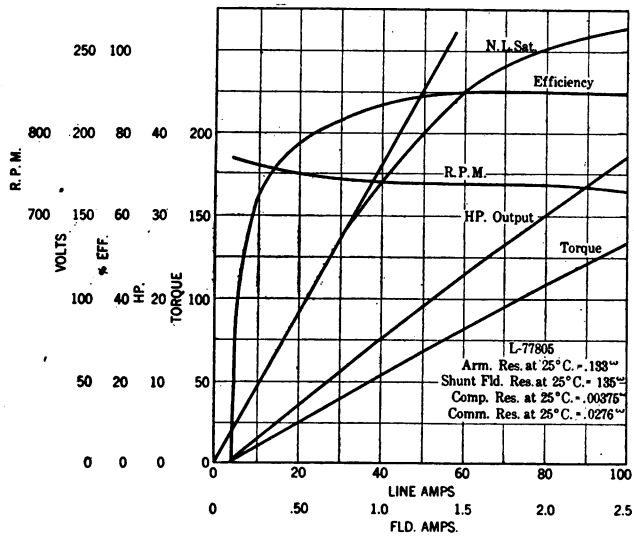


FIG. 22—CONSTANT-SPEED MOTOR—20-H. P.—230 VOLTS—750 REV. PER MIN.

as the motor was belted to a generator and there was very little friction to assist in bringing the load to rest.

Figs. 20 and 21 show dynamic braking with exactly the same conditions as the two previous curves, except the field rheostat was short-circuited during this braking period. The action of the shunt field in this case is very interesting. The increase in the field strength maintained the armature current at a fairly constant value over a considerable part of the retardation, the resultant torque curve showing very well sustained retarding effort. This indicates that the action on an adjustable speed motor gives very satisfactory results without the use of

Digitized by Google

additional steps in the dynamic brake resistance. Under normal operating conditions the friction load would be sufficient to bring the motor quickly to rest from the low speed. In the absence of considerable friction a mechanical brake should be used to obtain a quick stop, as very little dynamic braking can be obtained when the motor reaches low speeds.

Summary of Tests

1. It seems unnecessary, with automatic acceleration, to use more than one switch to short-circuit the armature resistor used with small motors except where specia' requirements are to

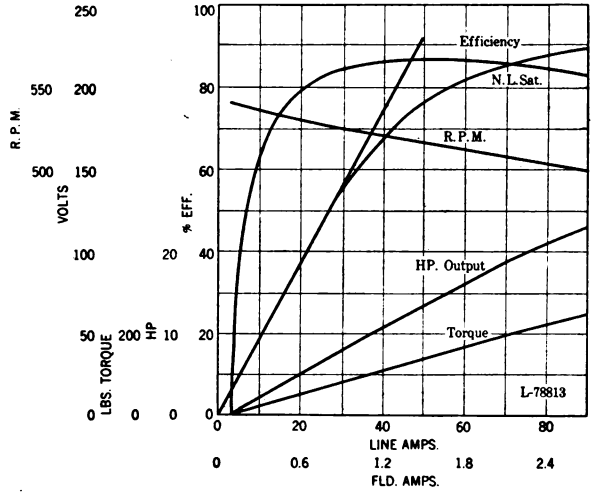


Fig. 23—Low-Speed—20-h. p. Motor—230-Volts—500 1500 rev. per min.

be met. I believe it is practicable to use one switch with motors as large as 15 h.p. for general purposes, and operate this switch by counter e.m.f., setting the switch to close at 75 per cent of normal voltage.

2. If the motor field is zero, or has a small value, when the line switch is closed, the starting torque is also zero or has only a small value and it will increase gradually so that the motor, or its load, will not be subjected to a heavy shock or jar when the lost motion in the drive is taken up.

3. The shunt field of small adjustable speed motors can be reduced in one step under normal load conditions without fear

Digitized by Google

of undue torque or current. I believe this practise can be safely followed with 50-h.p. motors and perhaps larger. This covers the usual range of sizes for this type of motor.

I believe that most machine tool motors are always started light. Under this condition the motor can be started successfully with minimum field strength and the field relay omitted. This will enable us to use the same controller for constant speed and adjustable speed motors supplying a separately mounted field rheostat for the latter.

4. Adjustable speed motors can use one step of resistance for dynamic braking as the change in field strength tends to

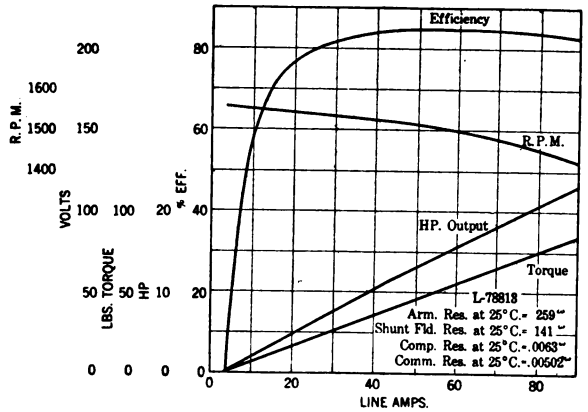


FIG. 24—HIGH-SPEED—20-H. P. MOTOR—230 VOLTS—500-1500 REV. PER MIN.

maintain the braking current constant over a considerable range of speed.

5. The use of a "vibrating" or "fluttering" relay is bad engineering for hand-operated field rheostats, unless a "transfer" relay is also used to reverse its action when the motor regenerates.

6. The time required to accelerate to 95 per cent of speed is very short. In these tests the time did not exceed three seconds.

NEW PROBLEMS

There are very few problems which present a more fertile field than the control of adjustable speed motors. The foregoing discussion covers only a few of the questions involved. The writer has observed cases where gearing has broken, due to

Digitized by Google

a momentary reverse torque of the motor. It is important to see that all interlocks or relays connected to the shunt field resistance are so arranged that they cannot cause a momentary reverse torque of the motor. After a positive torque has been applied to machinery, and all of the lost motion taken up, it is seldom that any part of the apparatus is injured, even if the driving torque varies over a considerable range, provided this torque is always positive. A slight negative torque allows lost motion to occur, and is apt to break some part of the apparatus, due to the hammering blow effect, when the positive torque is resumed.

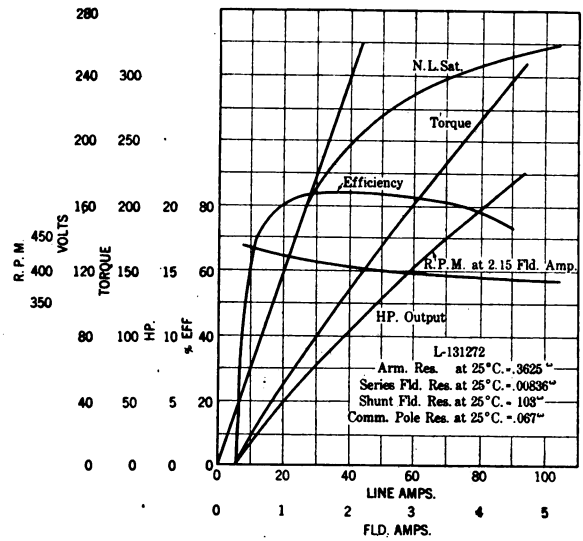


FIG. 25—LOW-SPEED—15-H. P. MOTOR—230 VOLTS—400-1600 REV. PER MIN.

This reverse torque may also be caused by a drop in the line voltage below the counter e.m.f. of the motor, or it may occur due to a rapid movement of the field rheostat.

Trouble may also result from increasing the field strength of a motor when it is disconnected from the line. For example, a 400 to 1600-rev. per min. motor is operating at its maximum speed. If the controller disconnects the motor armature from the line, and at the same time increases the field strength to its maximum value, the voltage across the brushes of the motor will rise to something over three times normal voltage, unless the armature is slowed down very quickly. It can readily be

Digitized by Google

seen that a 500-volt motor, having over 1700 volts across its brushes, is apt to flash across at some part of its insulation and untimately be damaged. This rise of voltage has actually been

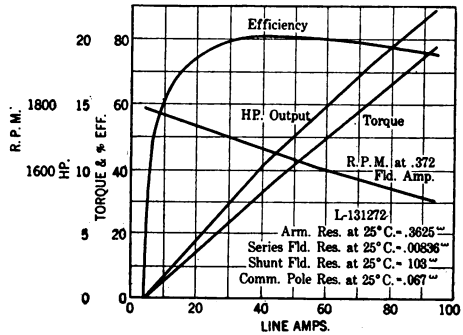


FIG. 26—HIGH-SPEED—15-H. P. MOTOR—230 VOLTS—400-1600 REV. PER MIN.

observed, and care must be taken not to manipulate the shunt field so as to cause it.

The use of dynamic braking introduces a good many interesting problems, both mechanical and electrical. The additional

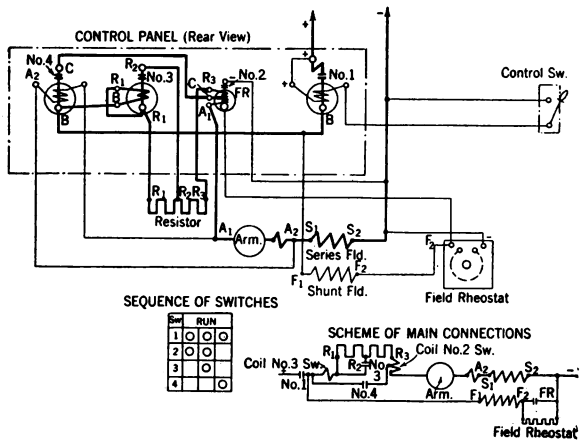


FIG. 27—DIAGRAM OF CONNECTIONS

heating effect on the motor is well known. The effect, however, upon the loading and lubrication of bearings, is not so well understood. The resultant change in the field flux of the motor, and the rate of change of current, are other problems.

Digitized by Google

The whole field of controller engineering presents many opportunities for the investigator. It has many problems that have not yet been solved, and I believe that engineers should not take the existing practise in controller engineering for granted, but study each application in a thorough manner, and design as simple a controller as possible for the work.

The author wishes to acknowledge the assistance of Professor D. Rowell, of Purdue University, in analyzing some of these curves and in making suggestions for future tests.

Digitized by Google

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 16, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

ANALYSIS OF STARTING CHARACTERISTICS OF DIRECT-CURRENT MOTORS

BY K. L. HANSEN

ABSTRACT OF PAPER

In this paper are derived the mathematical expressions for the current, speed, torque and power at any time during the accelerating period when a shunt, series or compound motor is connected to a supply line.

THE determination of the torque required to accelerate a given mass to any desired speed in a given time is a problem frequently met with in engineering practise. It has been shown in text books on mechanics, that the speed of a revolving mass after a time of t seconds is

$$\text{rev. per min.} = \frac{307.5 \times T_a \times t}{W \times G^2} \qquad (1)$$

where T_a = accelerating torque in pounds at one foot radius
W = weight in pounds
G = radius of gyration in feet.

Formula (1) holds only when the torque remains constant. In d-c. motors the torque is constant only when the current and flux remain constant. In many applications, especially where a smooth acceleration is required, as for example in starting trains, street cars, elevators, etc., this condition is approximately realized by gradually cutting out the starting resistance. With a sufficiently large resistance and a great number of steps, the current may be limited to a given percentage above normal (as 20 per cent or 25 per cent) and the torque may be considered constant.

There are, however, many applications in which the object is to accelerate as rapidly as the motors will stand, and the starting resistance has only a few steps or is left out altogether. In

Manuscript of this paper was received November 10, 1916.

Digitized by Google

such cases it is evident that the current and torque do not remain constant, and formula (**1**) would not hold. When a motor is thrown directly on the line or the starting resistance is low, the starting current may reach a value many times the normal current. It is then not sufficient merely to know the time required to accelerate to a certain speed, but the power developed by the windings must be determined to insure that dangerous overloads are not reached. There are, moreover, many industrial operations where the motor is started and reversed at frequent intervals and the power required for acceleration may be a considerable portion of the total load. In such cases it is necessary to know the r.m.s. value of the current in order to choose a motor with proper capacity and avoid excessive heating.

The problem then is to obtain mathematical expressions for the current, speed, torque and power at any time during the accelerating period when a motor is connected to a supply circuit. Closely connected with this, is the problem of dynamic braking where a revolving mass is brought to a stop by dissipating part of the stored energy in a resistance through which the armature windings have been short-circuited. Another application involving both phases of the problem is the flywheel motor-generator set, in which electrical energy is converted into mechanical energy and partly stored in a flywheel. At peak loads the stored energy is again converted into electrical energy.

Approximations of the speed, torque and current curves during the acceleration may be obtained by assuming the torque constant for a small period of time. The speed and current at the end of this period may then be calculated, and the torque based on this new value of the current again assumed constant for a small period. A sufficient number of points may be obtained by this step by step calculation to draw the curves. This method has the disadvantage, however, that it does not show at a glance the relation which the quantities entering into the problem bear to one another, and the way in which a change in one or more of them will modify the curves. This paper is an attempt to arrive at a more general solution.

Shunt Motors

It has been shown in numerous text books and articles on armature reaction in d-c. machines that there is no demagnetizing effect due to the main armature current when motors are operated on no-load neutral. There is, however, a distortion

Digitized by Google

of the main field under load due to cross-magnetization, and as the teeth and pole tips are usually saturated to some extent, the increase in flux on one side of the pole is less than the reduction on the other. The net result is then a decrease in the total flux per pole under load. In commutating-pole motors where relatively small air gaps are used, it is customary to supply a compensating winding in order to insure stability. It will be assumed that this winding is just about sufficient to compensate the flux reduction due to distortion, and the flux may be considered constant.

When the terminals of a shunt motor are connected with the supply line, the impressed voltage must be balanced by the counter e.m.f. due to resistance and the counter e.m.f. due to rotation. If R be the resistance of all circuits in series, the first of these is Ri. The counter e.m.f. of rotation is expressed by the formula

$$e = \frac{B \times T \times \phi \times K \times \text{rev. per min.}}{6 \times 10^6} \tag{2}$$

where B = number of commutator bars
T = number of turns in series per commutator bar
ϕ = flux per pole in kilolines
K = 2 in multiple wound armatures
= number of poles in two-circuit-wound armatures.

As previously stated, when the torque is constant, the acceleration is constant, and the speed is directly proportional to the accelerating torque and the time. When the torque is not constant the speed is no longer proportional to the time, but the time rate of change in speed is proportional to the accelerating torque and if S be the number of revolutions per minute;

$$\frac{dS}{dt} = \frac{307.5 \times T_a}{W \times G^2} \tag{3}$$

when starting from standstill the speed at any time t is

$$S = \frac{307.5}{W \times G^2} \int_0^t T_a \, dt \tag{4}$$

The accelerating torque T_a is the difference between the torque developed by the motor windings and the counter torque.

Digitized by Google

The torque developed by the windings expressed in pounds at one foot radius is

$$\text{Torque} = \frac{B \times T \times \phi \times K \times i_a}{8.52 \times 10^5} \qquad (5)$$

Where i_a is the armature current and the remaining symbols have the same meaning as in the counter e.m.f. formula.

The counter torque T_c consists of bearing friction, windage, hysteresis and the friction load. The friction load may be approximately constant or may vary with the speed, according to some law, in which case it can be expressed as a function of the speed. Assume first, the counter torque to be constant; the accelerating torque then is

$$T_a = \frac{B \times T \times \phi \times K \times i_a}{8.52 \times 10^5} - T_c \qquad (6)$$

Substitute formula (6) in speed formula (4)

$$S = \frac{307.5}{W \times G^2} \int_0^t \frac{B \times T \times \phi \times K \times i_a}{8.52 \times 10^5} - T_c \, dt \qquad (7)$$

Substituting formula (7) for rev. per min. in formula (2) for induced volts, we get

$$e = \frac{6 \times (B \times T \times \phi \times K)^2}{10^{11} \times W \times G^2} \int_0^t i_a \, dt$$

$$- \int_0^t \frac{5.12 \times B \times T \times \phi \times K}{10^5 \times W \times G^2} T_c \, dt \qquad (8)$$

Let $K_1 = \frac{6 \times (B \times T \times \phi \times K)^2}{10^{11} \times W \times G^2}$ and $K_2 = \frac{5.12 \times B \times \phi \times K}{10^5 \times W \times G^2}$

The e.m.f. equation may then be written:—

$$E = R\, i_a + K_1 \int_0^t i_a \, dt - K_2 \int_0^t T_c \, dt \qquad (9)$$

Equation (9) is not complete because it does not take into account the counter e.m.f. of self induction and the mutual induction between the shunt and compensating coil. It will be shown later that the effect of these is of so short duration, com-

Digitized by Google

pared with time to accelerate to full speed, that, except in special cases, they may be omitted.

Differentiating equation (9) with respect to t to free it from integral sign,

$$R\frac{d\,i_a}{d\,t} + K_1\,i_a - K_2\,T_c = 0$$

Dividing by R and transposing,

$$\frac{d\,i_a}{d\,t} + \frac{K_1}{R}\,i_a = \frac{K_2\,T_c}{R}$$

A linear differential equation of first order integrated by the equation

$$i_a = \epsilon^{-\frac{K_1}{R}t}\int \epsilon^{-\frac{K_1}{R}t}\,\frac{K_2\,T_c}{R}\,d\,t + A\,\epsilon^{-\frac{K_1}{R}t}$$

where A is a constant of integration.

Integrating and reducing we have

$$i_a = \frac{K_2}{K_1}\,T_c + A\,\epsilon^{-\frac{K_1}{R}t}$$

If $i_a = I_0$ when $t = 0$ then

$$A = I_0 - \frac{K_2}{K_1}\,T_c$$

and

$$i_a = \frac{K_2}{K_1}\,T_c + \left(I_0 - \frac{K_2}{K_1}\,T_c\right)\epsilon^{-\frac{K_1}{R}t}$$

when starting from a standstill $I_0 = \frac{E}{R}$ and therefore

$$i_a = \frac{K_2}{K_1}\,T_c + \left(\frac{E}{R} - \frac{K_2}{K_1}\,T_c\right)\epsilon^{-\frac{K_1}{R}t} \qquad (10)$$

After a theoretically infinite (but practically very short) time the term containing the factor $\epsilon^{-\frac{K_1}{R}t}$ becomes equal to zero and the current becomes $\frac{K_2}{K_1}\,T_c$, which is the current required to develop full-load torque. From the value of the current, the speed and torque and power output can easily be calculated.

Digitized by Google

If the service is intermittent and the motor is on the line for a period of t_1 seconds and the shut down for t_2 seconds, the r.m.s. or effective value of the current is

$$I_{eff.} = \sqrt{\int_0^{t_1} \frac{i^2\,dt}{t_1 + t_2}}$$

$$= \frac{1}{\sqrt{t_1 + t_2}} \sqrt{\int_0^{t} i^2\,d\,t}$$

$$= \frac{1}{\sqrt{t_1 + t_2}} \sqrt{\int_0^{t_1} \left[\left(\frac{E}{R} - \frac{K_2}{K^1}\,T_c\right)\epsilon^{-\frac{K_1}{R}t} + \frac{K_2}{K_1}\,T_c\right]^2 d\,t}$$

$$= \frac{1}{\sqrt{t_1 + t_2}} \sqrt{\frac{R}{2\,K_1}\left(\frac{E}{R} - \frac{K_2}{K_1}\,T_c\right)^2\left(1 - \epsilon^{-\frac{2\,K_1}{R}t_1}\right) + \frac{2\,R\,K_2\,T_c}{K_1^2}\left(\frac{E}{R} - \frac{K_2}{K_1}\,T_c\right)\left(1 - \epsilon^{-\frac{K_1}{R}t}\right) + \frac{K_2^2\,T_c^2\,t_1}{K_1^2}}$$

If t is sufficiently long to let the motor come up to speed, the terms containing the factors $\epsilon^{-\frac{2K_1}{R}t_1}$ and $\epsilon^{-\frac{K_1}{R}t}$ become negligible, and we have

$$I_{eff.} = \frac{1}{\sqrt{t_1 + t_2}} \sqrt{\frac{R}{2\,K_1}\left(\frac{E}{R} - \frac{K_2}{K_1}\,T_c\right)^2 + \frac{2\,R\,K_2\,T_c}{K_1^2}\left(\frac{E}{R} - \frac{K_2}{K_1}\,T_c\right) + \frac{K_2^2\,T_c^2\,t_1}{K_1^2}}$$

Digitized by Google

If the counter torque T_c is neglected, formula (**10**) reduces to

$$i_a = \frac{E}{R} \epsilon^{-\frac{K_1}{R} t} \tag{11}$$

The instantaneous value of the power input is

$$P_i = E_i = \frac{E^2}{R} \epsilon^{-\frac{K_1}{R} t} \tag{12}$$

The total watt-seconds energy to bring the motor up to speed is

$$\int_0^\infty P_i \, dt = \frac{E^2}{R} \int_0^\infty \epsilon^{-\frac{K_1}{R} t} \, dt$$

$$= \left[-\frac{E}{K_1} \epsilon^{-\frac{K_1}{R} t} \right]_0^\infty = \frac{E^2}{K_1}$$

The total energy expended in heating the windings is

$$\int_0 R i^2 \, dt = \frac{E^2}{R} \int_0^\infty \epsilon^{-\frac{2K_1}{R} t} \, dt$$

$$= \frac{E^2}{2 K_1}$$

The instantaneous value of the power output is

$$P_o = (E - R i) \, i = \frac{E^2}{R} \epsilon^{-\frac{K_1}{R} t} - \frac{E^2}{R} \epsilon^{-\frac{2K_1}{R} t}$$

and the total energy developed by the motor windings is

$$\int_0^\infty P_o \, dt = \frac{E^2}{R} \int_0^\infty \epsilon^{-\frac{K_1}{R} t} - \frac{E^2}{R} \int_0^\infty \epsilon^{-\frac{2K_1}{R}} \, dt$$

$$= \frac{E^2}{K_1} - \frac{E^2}{2 K_1} = \frac{E^2}{2 K_1} \tag{13}$$

Digitized by Google

which is the energy stored in the revolving parts. If T_c is negligible, the counter e.m.f. at full speed becomes equal to the impressed e.m.f. Substituting the values of E (or e) and K_1 in this formula and multiplying by $\frac{550}{746}$ to convert from watt-seconds to foot-pounds, we have

$$\text{Foot-Pounds} = \frac{1}{5860} (\text{rev. per min.})^2 \times W \times G^2$$

$$= \frac{1}{2 \times 32.2} \times \left(\frac{2\pi \times \text{rev. per min.}}{60}\right)^2 \times G^2 \times W \quad (14)$$

which is the usual expression for the energy stored in a revolving mass. Hence the total energy input is divided in two halves, one half being expended in heating the windings and the other half stored in the rotating mass.

This result can be arrived at directly from physical considerations. Suppose a motor to be running at no load and that the friction losses are negligible. The counter e.m.f. is equal to the impressed e.m.f. E, and if the motor terminals are disconnected from the line and short-circuited upon themselves, the momentary value of the short-circuit current (neglecting self-induction) is $\frac{E}{R}$. The torque developed by the motor windings now becomes the counter or decelerating torque, and if a constant flux is maintained, the current decreases to zero in the same manner as when accelerating from stand still to full speed. The copper losses in the two cases are therefore the same, and in the decelerating case the only way in which the stored energy can be dissipated is in heating the windings. When accelerating from zero to full speed, the energy stored in the moving parts is therefore equal to the energy dissipated in the resistance. While the copper losses in the two cases are the same, from the standpoint of commutation, the condition is much more severe when the windings are short-circuited and the motor brought to a stop. The induced voltage and current are in that case a maximum at the same instant and the maximum power is much greater.

As an illustration, consider a 5-h.p., 230-volt, 525-rev. per min motor with the following characteristics: $R = 1.8$, $B = 111$, $T = 6$ and $\Phi = 840$.

Digitized by Google

Constant Torque. Assume the moment of inertia of the armatures and load $= W \times G^2 = 75$

Hence,

$$K_1 = \frac{6 \times (111 \times 6 \times 840 \times 4)^2}{10^{11} \times 75} = 4$$

$$K_2 = \frac{5.12 \times 2{,}240{,}000}{10^5 \times 75} = 1.53$$

$$T_c = 50$$

Armature current at full load $\frac{K_2}{K_1} T_c = 19.2$ amperes

From (**10**) we get: $i_a = (128 - 19.2)\, \epsilon^{-\frac{4}{18}t} + 19.2$

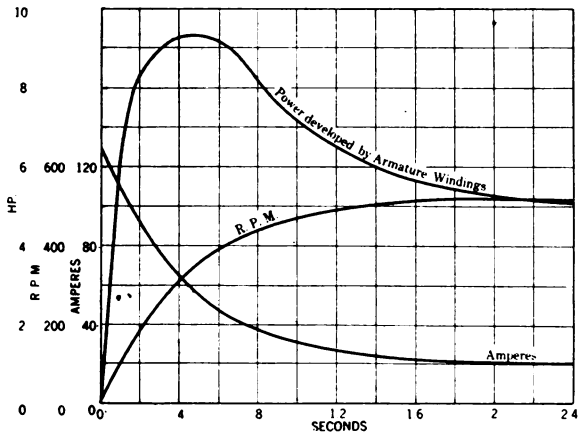


FIG. 1

The current, speed and power curves are shown in Fig. 1 plotted against time in seconds, as abscissa.

Assuming now that a resistance is inserted to limit the starting current to approximately three times the full-load current. This would require a total resistance of four ohms or an external resistance of 2.2 ohms. The curves are shown in Fig. 2. It will be noticed that the maximum power output when the resistance is cut out is almost as great as when no resistance was used. In order to limit the power output the resistance must be cut out in two or more steps.

So far in this discussion it has been assumed that the counter torque was constant. In practise it may be approximately con-

Digitized by Google

stant or may vary with the speed in a great variety of ways, giving rise to many interesting problems. It may vary periodically becoming zero at regular intervals, and it may become negative or in the same direction as the motor torque through part of the cycle.

Varying Counter Torque. As an illustration of a case in which the torque is some function of the speed assume that the torque varies as the square of the speed. A direct-connected fan is an example of this, because the air pressure and consequently the torque varies as the square of the speed.

The counter torque may then be expressed as the product of a constant and the square of the speed thus:

$$T_c = C S^2$$

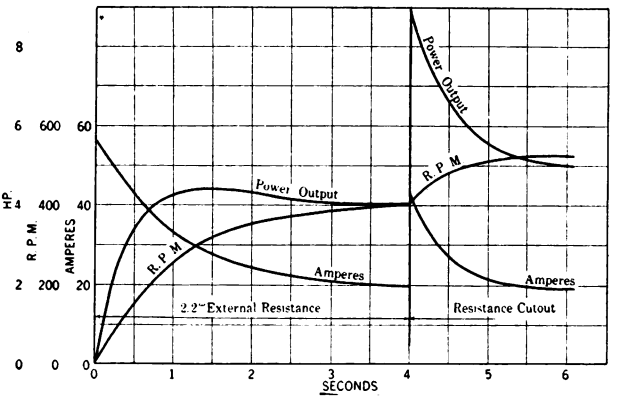


FIG. 2

and the accelerating torque becomes

$$T_a = \frac{B \times T \times \phi \times K \times i_a}{8.52 \times 10^5} - C S^2 \qquad (15)$$

Substituting then in formula (**15**) the value of S,

$$S = \frac{e \times 6 \times 10^6}{B \times T \times \phi \times K} = \frac{(E - R i_a) \times 6 \times 10^6}{B \times T \times \phi \times K}$$

$$T_a = \left\{ \frac{B \times T \times \phi \times K \times i_a}{8.52 \times 10^5} - C \left[\frac{(E - R i_a) \times 6 \times 10^6}{B \times T \times \phi \times K} \right]^2 \right\}$$

Digitized by Google

As in (**3**) the time-rate of change of speed equals accelerating torque:

$$\frac{d\,s}{d\,t} = \frac{307.5}{W \times G^2} \left\{ \frac{B \times T \times \phi \times K \times i_a}{8.52 \times 10^5} - C\left[\frac{(E - R\,i_a) \times 6 \times 10^6}{B \times T \times \phi \times K}\right]^2 \right\} \qquad (16)$$

As before the sum of the induced volts and the $R\,i_a$ drop must be equal to the impressed volts thus:

$$E = R\,i_a + \frac{B \times T \times \phi \times K}{6 \times 10^6}\,S$$

Differentiating with respect to t

$$R\frac{d\,i_a}{d\,t} + \frac{B \times T \times \phi \times K}{6 \times 10^6}\,\frac{d\,s}{d\,t} = 0$$

Substituting the value of $\frac{d\,s}{d\,t}$ from (**16**)

$$R\frac{d\,i_a}{d\,t} + \frac{307.5}{W \times G^2} \times \frac{B \times T \times \phi \times K}{6 \times 10^6} \left\{ \frac{B \times T \times \phi \times K\,i_a}{8.52 \times 10^5} - C\left[\frac{(E - R\,i_a) \times 6 \times 10^6}{B \times T \times \phi \times K}\right]^2 \right\} = 0$$

Multiplying and reducing

$$R\frac{d\,i_a}{d\,t} + \frac{6 \times (B \times T \times \phi \times K)^2}{10^{11} \times W \times G^2}\,i_a - \frac{1.845 \times 10^9}{W \times G^2 \times B \times T \times \phi \times K}\,C\,(E - R\,i_a)^2 = 0$$

now let $K_1 = \frac{6 \times (B \times T \times \phi \times K)^2}{10^{11} \times W \times G^2}$

Digitized by Google

and $K_2 = \dfrac{1.845 \times 10^9 \times C}{B \times T \times \phi \times K \times W \times G^2}$

$$R \frac{d\, i_a}{d\, t} + K_1\, i_a - K_2\, (E - R\, i_a)^2 = 0$$

$$R \frac{d\, i_a}{d\, t} - K_2\, E^2 + (K_1 + 2\, K_2\, R\, E)\, i_a - K_2\, R^2\, i_a^2 = 0$$

$$- \frac{R\, d\, i_a}{K_2\, E^2 + (K_1 + 2\, K_2\, R\, E)\, i_a - K_2\, R^2\, i_a^2} = - d\, t$$

Let $K_2\, E^2 = a$, $K_1 + 2\, K_2\, R\, E = 2\, b$, $K_2\, R^2 = c$, and substitute,

$$\frac{R\, d\, i_a}{-a + 2\, b\, i_a - c\, i_a} = - d\, t$$

Multiplying numerator and denominator by c,

$$\frac{R\, d\, c\, i_a}{-a\, c + 2\, b\, c\, i_a - c^2\, i_a^2} = - d\, t$$

adding and subtracting b^2 in the denominator,

$$\frac{R\, d\, c\, i_a}{b^2 - a\, c - (c^2\, i_a^2 - 2\, b\, c\, i_a + b^2)} = - d\, t$$

$d\, (c\, i_a - b) = d\, c\, i_a\, b$ being a constant, hence

$$\frac{R\, d\, (c\, i_a - b)}{b^2 - a\, c - (c\, i_a - b)^2} = - d\, t$$

$$R \int \frac{d\, (c\, i_a - b)}{b^2 - a\, c - (c\, i_a - b)^2} + \text{a constant of integration} = - t \quad (17)$$

The expression under the integral sign is of the form $\dfrac{d\, x}{p^2 - x^2}$ which is integrated by $\displaystyle\int \frac{d\, x}{p^2 - x^2} = \frac{1}{2\, p} \log \left[\frac{p + x}{p - x}\right]$

Digitized by Google

Integrating (**17**)

$$\frac{R}{2\sqrt{b^2-ac}}\log\left[\frac{\sqrt{b^2-ac}+(c\,i_a-b)}{\sqrt{b^2-ac}-(c\,i_a-b)}\right]+\text{a constant}=-t$$

Let constant of integration $=-\dfrac{R}{2\sqrt{b^2-ac}}\log A$

and we have

$$\frac{R}{2\sqrt{b^2-ac}}\left\{\log\left[\frac{\sqrt{b^2-ac}+(c\,i_a-b)}{\sqrt{b^2-ac}-(c\,i_a-b)}\right]-\log A\right\}=-t$$

$$\frac{\sqrt{b^2-ac}+(c\,i_a-b)}{\sqrt{b^2-ac}-(c\,i_a-b)}=A\,\epsilon^{-\frac{2\sqrt{b^2-ac}}{R}} \qquad (18)$$

Now when $t=0$ $\quad i=\dfrac{E}{R}$ and

$$A=\frac{R\sqrt{b^2-ac}+cE-bR}{R\sqrt{b^2-ac}-cE+bR}$$

Solving equation (**18**) for i_a

$$i_a=\frac{A\,\epsilon^{-\frac{2\sqrt{b^2-ac}}{R}t}(\sqrt{b^2-ac}+b)-\sqrt{b^2-ac}+b}{c\left(1+A\,\epsilon^{-\frac{2\sqrt{b^2-ac}}{R}t}\right)} \qquad (19)$$

Using same illustration as before $C\times(525)^2=50$, $C=0.000182$ $K_1=4$, $K_2=0.00199$, $a=105$ $b=2.83$ $c=0.00642$ $\sqrt{b^2-ac}=2.705$, $A=0.148$ and substituting in (**19**) and reducing

$$i_a=\frac{0.817\,\epsilon^{-3t}+0.125}{0.00642\,(1+0.148\,\epsilon^{-3t})}$$

The curves are shown in Fig. 3. The current decreases and the speed rises more rapidly than with constant torque, but the dif-

Digitized by Google

ference is not very marked because the counter torque is small compared with the motor torque.

If, as before, we assume an external resistance of 2.2 ohms inserted in the armature circuit, we have

$$R = 4,\ K_1 = 4,\ K_2 = 0.00199,\ a = 105,\ b = 3.85$$
$$c = 0.0318,\ A = 0.25$$

then
$$i_a = \frac{1.82\,\epsilon^{-1.69t} + 0.47}{0.0318\,(1+0.25\,\epsilon^{-1.69t})}$$

The curves are shown in Fig. 4 and it will be noticed that the difference between these and the ones shown in Fig. 2 is more pronounced.

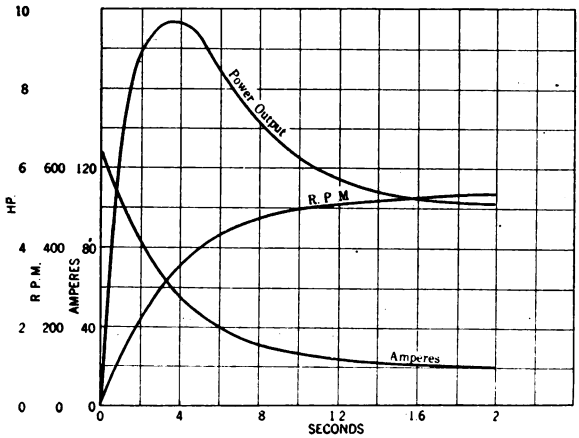


FIG. 3

In general when a motor is thrown directly on the line the difference between the curves taken with and without a friction load is hardly noticeable, the shape of the curves and time required for acceleration being determined almost entirely by the inertia of the mass to be accelerated. As the starting resistance increases, however, the counter torque becomes of increasing importance.

SERIES MOTORS

In series motors the flux is not constant, but must be expressed as a function of the current. As was first shown by Frölich, the flux can approximately be represented by a parabolic curve.

$$\Phi = \frac{\phi\, i}{1 + b\, i}$$

Digitized by Google

Where ϕ is the flux per ampere at low density. A still closer approximation can be obtained if a constnat a is substituted for 1, thus

$$\Phi = \frac{\phi\, i}{a + b\, i}$$

Substituting this value of the flux in formula (**5**) the torque becomes,

$$\text{Torque} = \frac{B \times T \times K \times \phi \times i^2}{8.52 \times 10^5 \times (a + b\, i)}$$

and if the counter torque be neglected, the speed is

$$\text{Rev. per min.} = \frac{307.5 \times B \times T \times K \times \phi}{8.52 \times 10^5 \times W \times G^2} \int \frac{i^2\, d\, t}{a + b\, i}$$

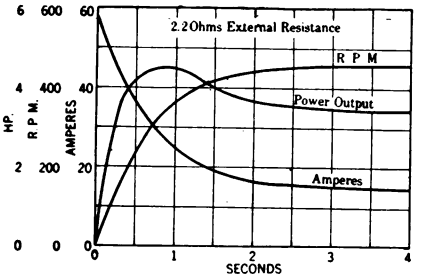


FIG. 4

Substituting these values of flux and speed in formula (**2**) we have for induced volts

$$e = \frac{6 \times (B \times T \times K \times \phi)^2}{10^{11} \times W \times G^2} \frac{i}{a + b\, i} \int \frac{i^2\, d\, t}{a + b\, i}$$

Let

$$\frac{6 \times (B \times T \times K \times \phi)^2}{10^{11} \times W \times G^2} = K_1$$

The e.m.f. equation then becomes

$$R\, i + \frac{K_1\, i}{a + b\, i} \int \frac{i^2\, d\, t}{a + b\, i} = E$$

Dividing by $\left(\frac{i}{a + b\, i}\right)$

$$R\, a + b\, R\, i + K_1 \int \frac{i^2\, d\, t}{a + b\, i} = \frac{a\, E}{i} + b\, E$$

Digitized by Google

Differentiating with respect to t:

$$b\,R\frac{d\,i}{d\,t}+K_1\frac{i^2}{a+b\,i}=-\frac{a\,E}{i^2}\frac{d\,i}{d\,t}$$

Dividing by $\frac{i^2}{a+b\,i}$

$$\left(\frac{b\;a\;R}{i^2}+\frac{b^2\,R}{i}\right)\frac{d\,i}{d\,t}+K_1=-\left(\frac{a^2\;E}{i^4}+\frac{b\;a\;E}{i^3}\right)\frac{d\,i}{d\,t}$$

Transposing:

$$\left(\frac{b^2\;R}{i}+\frac{b\;a\;R}{i^2}+\frac{b\;a\;E}{i^3}+\frac{a^2\;E}{i^4}\right)\frac{d\,i}{d\,t}+K_1=0$$

$$b^2\,R\int\frac{d\,i}{i}+b\,a\,R\int\frac{d\,i}{i^2}+b\,a\,E\int\frac{d\,i}{i^3}$$

$$+a^2\,E\int\frac{d\,i}{i^4}+K_1\int d\,t=A$$

$$b^2\,R\log i-\frac{b_a\;R}{i}-\frac{b_a\;E}{2\,i^2}-\frac{a^2\;E}{3\,i^3}+K_1\,t=A$$

$$t=\frac{A+\frac{b\;a\;R}{i}+\frac{b\;a\;E}{2\,i^2}+\frac{a^2\;E}{3\,i^3}-b^2\,R\log i}{K_1} \tag{20}$$

If $\log i$ is taken to the base 10, the last term must be multiplied by $\frac{1}{\log_{10}\epsilon}=2.31$ thus:

$$t=\frac{A+\frac{b\;a\;R}{i}+\frac{b\;a\;E}{2\,i^2}+\frac{a^2\;E}{3\,i^3}-2.31\,b^2\,R\log_{10}i}{K_1} \tag{21}$$

Digitized by Google

The constant of integration A is found from the initial condition when $t = 0$ $i = \frac{E}{R}$

Assume that the shunt and compensating coils have been removed and the motor supplied with a series field of 100 turns per coil. The resistance of the main circuit will be changed to 2.3 ohms, and the following constants are found from the saturation curve:

$$\phi = 56, \quad a = 0.62, \quad b = 0.041$$

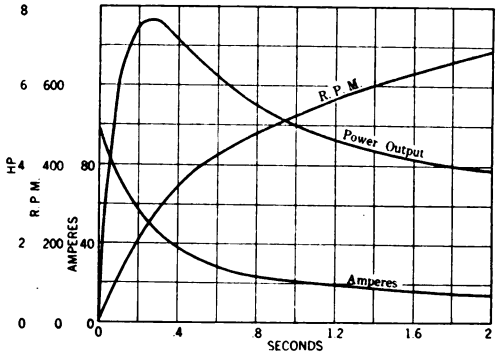


FIG. 5

Hence

$$K_1 = \frac{6 \times (11 \times 6 \times 4 \times 56)^2}{10^{11} \times 75} \quad 0\ 0.0177 \quad A = 0.0169$$

$$t = \frac{0.0169 + \frac{0.0584}{i} + \frac{2.92}{i^2} + \frac{29.5}{i^3} - 0.0089 \log_{10} i}{K_1}$$

The curves are shown in Fig. 5 and it will be noticed that compared with the shunt machine, Fig. 1, the current falls more rapidly at the start, due to the heavy torque, but the approach to the final value is more gradual as the flux decreases with the current. It will be further noticed that the speed rises above normal and, under the assumption made of no counter torque, would continue to rise. This is a condition which of course would not be likely to occur in practise, as a series motor should

Digitized by Google

ever be applied where there is a possibility that its load may be entirely removed. If a counter torque, corresponding to the full-load torque had been assumed, the first part of the curves would not be greatly modified, but at about 0.6 or 0.7 of a second, the speed and power curves bend rather sharply, and gradually approach their final values.

The curves also indicate that in case of compound motors with the usual amount of compounding, it is sufficiently accurate to use an average value of the flux and assume it constant over the accelerating period.

Compound Motors

Effect of Self and Mutual Induction Considered. It has been stated that the effect of self and mutual induction is usually not sufficient to appreciably modify the curves. There are cases, however, in which the peak value of the current may be reduced considerably by self-induction, and while the mutual induction between the shunt and series coils has practically no effect on the acceleration, it is interesting to note the change in the shunt-field current due to the main current. The discussion of the self and mutual induction is best taken up in connection with the study of the compound motor, because the series field is strong enough to have marked effect on the shunt-field current.

It has already been pointed out that when the flux varies over a small range, an average constant value of the flux can be used, and the counter e.m.f. due to rotation is as before (neglecting counter torque),

$$e = K_1 \int i_a \, d\,t$$

Let L_1 = coefficient of self induction of main circuit, L_2 = coefficient of self induction of shunt field, M = mutual induction between main circuit and shunt field, r_f = resistance of shunt field.

We have for the differential equation of main circuit:

$$L_1 \frac{d\,i_a}{d\,t} + M \frac{d\,i_f}{d\,t} + R\,i_a + K_1 \int i_a \, d\,t = E \qquad (22)$$

and for the differential equation of shunt-field circuit,

$$L_2 \frac{d\,i_f}{d\,t} + M \frac{d\,i_a}{d\,t} + r_f\,i_f = E \qquad (23)$$

Digitized by Google

Differentiating equation (**22**) with respect to t, to free it from integral sign,

$$L_1 \frac{d^2 i_a}{d t^2} + M \frac{d^2 i_f}{d t^2} + R \frac{d i_a}{d t} + K_1 i_a = 0 \qquad (\mathbf{24})$$

In symbolic notation, equations (**23**) and (**24**) may be written:

$$\begin{aligned} L_1 D^2 i_a + M D^2 i_f + R D i_a + K_1 i_a &= 0 \\ L_2 D i_f + M D i_a + r_f i_f &= E \end{aligned}$$

As the operator D obeys the commutative and distributive laws of algebra, these equations can be treated algebraically thus:

$$\begin{aligned} (L_1 D^2 + R D + K_1) i_a + M D^2 i_f &= 0 \\ M D i_a + (L_2 D + r_f) i_f &= E \end{aligned}$$

eliminating i_f

$$\begin{vmatrix} (L_1 D^2 + R D + K_1) & M D^2 \\ M D & L_2 D + r_f \end{vmatrix} i_a = \begin{vmatrix} 0 & M D^2 \\ E & (L_2 D + r_f) \end{vmatrix}$$

expanding the determinants

$$[(L_1 L_2 - M^2) D^3 + (L_2 R + L_1 r_f) D^2 + (L_2 K_1 + r_f R) D + r_f K_1] i_a = 0$$

Let $L_1 L_2 - M^2 = M_1$, $L_2 R + L_1 r_f = M_2$, $L_2 K_1 + r_f R = M_3$, $r_f K_1 = M_4$ the auxiliary equation becomes

$$M_1 D^3 + M_2 D^2 + M_3 D + M_4 = 0$$

This cubic can be solved algebraically by Cardan's method, but it is usually easier to substitute the numerical values of the coefficients and solve by Horner's method of approximation.

If a_1, a_2, a_3, are the roots of the cubic, the solution of the differential equation is

$$i_a = A_1 \epsilon^{a_1 t} + A_2 \epsilon^{a_2 t} + A_3 \epsilon^{a_3 t} \qquad (\mathbf{25})$$

where A_1 A_2 and A_3 are constants of integration.

The term $M \frac{d i_a}{d t}$ can then be expressed as a function of the time $f(t)$ and if substituted in equation (**23**) it becomes

$$L_2 \frac{d i_f}{d t} + r_f i_f = E - f(t)$$

Digitized by Google

a linear equation of first degree, the solution of which is

$$i_f = \frac{1}{L_2}\,\epsilon^{-\frac{r_f}{L_2}t}\int \epsilon^{\frac{r_f}{L_2}t}\,(E - f(t)\,dt$$

The self induction of the main circuit of a d-c. machine when the field is excited to a point somewhat above the knee of the saturation curve, is due almost entire y to the distortion of the main field and is nearly constant over a wide range in armature current. It does, however, decrease with the saturation of the main field. With no field excitation the flux set up by the armature m.m.f. can be estimated, and the number of interlinkages of this flux with the armature conductors divided by the square of the number of circuits in parallel is the coefficient of self induction. The field excited by self induction is estimated in the same way except that the saturation must be taken into account. The self induction of the series field is usually very small compared with that of the armature.

When the armature current of a compound motor is suddenly increased, the effect on the magnetic circuit is two-fold. The series field tends to increase the flux and the cross-magnetization of the armature tends to decrease it. If the net result is to increase the flux, and it usually is in a compound motor, an e.m.f. will be set up in the shunt field of such direction as to momentarily reduce the field current or even reverse it. The flux does not increase uniformily, however, but increases rapidly at the start and becomes almost constant for large values of the current. The mutual induction is therefore not constant, but as the total change in flux is comparatively small, it is sufficiently accurate to use an average value and consider it so.

A 7 ½-h.p., 230-volt, 1150-rev. per min. motor has the following constants:

$$L_1 = 0.012,\ M = 0.13,\ L_2 = 40,\ R = 0.58,\ r_f = 410,\ \Phi = 765,\ B = 99,\ T = 4$$

Let moment of inertia $= W \times G^2 = 130$ ft-lb.

We then have

$$L_1 L_2 - M^2 = 0.463,\ L_2 R + L_1 r_f = 20.12,\ L_2 K_1 + r_f R = 265.4\ r_f K_1 = 282$$

and the auxiliary equation is

$$0.463\,D^3 + 28.12\,D^2 + 265.4\,D + 282 = 0$$

Digitized by Google

The roots of this equation are

$$-1.22 \qquad -11.5 \qquad -47.8$$

and

$$i_a = A_1 \epsilon^{-1.22t} + A_2 \epsilon^{-11.5t} + A_3 \epsilon^{-47.8t}$$

$$M \frac{d i_a}{d t} = -0.158 A_1 \epsilon^{-1.22t} - 1.49 A_2 \epsilon^{-11.5t} - 6.2 A_3 \epsilon^{-47.8t}$$

substituting in equation (**23**)

$$L_2 \frac{d i_f}{d t} + r_f i_f = E + 0.158 A_1 \epsilon^{-1.22t} + 1.49 A_2 \epsilon^{-11.5t} + 6.2 A_3 \epsilon^{-47.8t}$$

Solving

$$i_f = \epsilon^{-\frac{r_f}{L_2}t} \int \epsilon^{-\frac{r_f}{L_2}t} \left[\frac{E}{L_2} + 0.00395 A_1 \epsilon^{-1.22t} + 0.0372 A_2 \epsilon^{-11.5t} + 0.155 A_3 \epsilon^{-47.8t} \right] d t$$

Integrating and multiplying out

$$i_f = \frac{E}{r_f} + 0.000435 A_1 \epsilon^{-1.22t} - 0.031 A_2 \epsilon^{-11.5t} - 0.00413 A_3 \epsilon^{-47.8t}$$

The e.m.f. due to rotation is

$$e = K_1 \int i_a d t = E - \left(L_1 \frac{d i_a}{d t} + M \frac{d i_f}{d t} + R i_a \right)$$

Substituting the value of i_a and i_f

$$e = 230 - 0.5663 A_1 \epsilon^{-1.22t} - 0.4877 A_2 \epsilon^{-11.5t} - 0.0257 A_3 \epsilon^{-47.8t}$$

Now when $t = 0 \quad i_a = 0 \quad i_f = \frac{E}{r_f} \quad e = 0$

Digitized by Google

and we have for equations of integration constants

$$A_1 + A_2 + A_3 = 0$$
$$0.000435\,A_1 - 0.031\,A_2 - 0.00413\,A_3 = 0$$
$$0.5663\,A_1 + 0.4877\,A_2 + 0.0257\,A_3 = 230$$

solving these equations

$$A_1 = 372,\ A_2 = 63,\ A_3 = -435$$

Hence

$$i_a = 372\,\epsilon^{-11.22t} + 63\,\epsilon^{-11.3t} - 435\,\epsilon^{-47.8t}$$
$$i_f = 0.56 + 0.162\,\epsilon^{-1.22t} - 1.95\,\epsilon^{-11.5t} + 1.8\,\epsilon^{-47.8t}$$

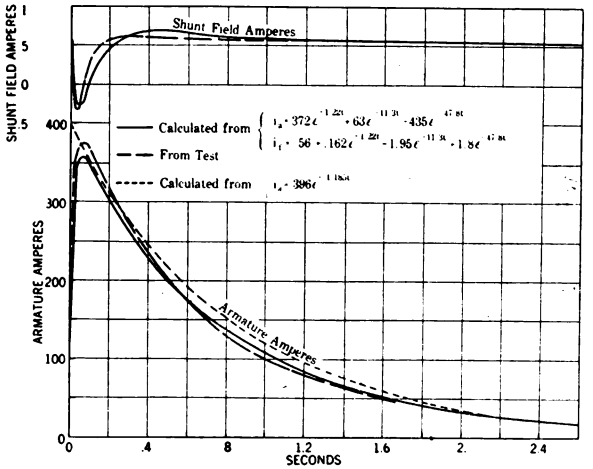


FIG. 6

The curves are shown in Fig. 6 and it will be noticed that the discrepancy between the calculated and tested shunt amperes is rather marked, due to the fact the mutual induction is not constant as was assumed.

In Fig. 7 are shown the calculated and tested curves with the flywheel effect reduced to approximately 35 and 6 ft-lb. With a starting resistance of one ohm being inserted in series with the armature, formula (1) becomes:

$$i_a = 146\,\epsilon^{-.435t}$$

The curves are shown in Fig. 8, the broken line being taken from the oscillogram.

Digitized by Google

In many applications of self-starting motors the shunt field is not excited before the armature circuit is closed, but the two are connected to the supply line simultaneously. It is evident that in all such cases the series field must be depended on to supply the accelerating torque at the start, because not only does it

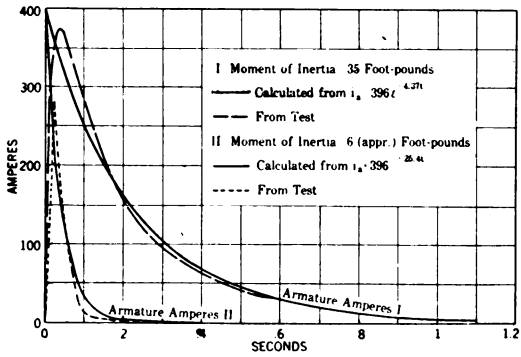


FIG. 7

take the shunt-field current an appreciable time to reach its full value due to its high self-induction, but at the instant the switch is closed it rises in the opposite direction on account of transformer action of series field. An exact mathematical solution is complicated, but a composite curve can be made up considering

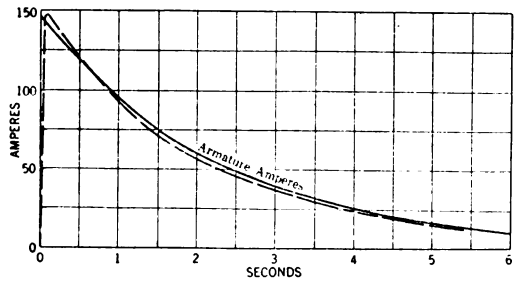


FIG. 8

the motor as series wound at the start and compound when approaching the final condition. The oscillograms shown in Fig. 9 were taken with the armature and shunt field circuits closed simultaneously.

A striking resemblance between these equations and those of the condenser charge is apparent, and such was indeed to be

Digitized by Google

expected. In the condenser charge the potential at the condenser terminals is proportional to $\int i\,dt$, and the stored energy to e^2, where e is the final value of the terminal voltage. With constant flux the counter e.m.f. of a rotating motor armature is

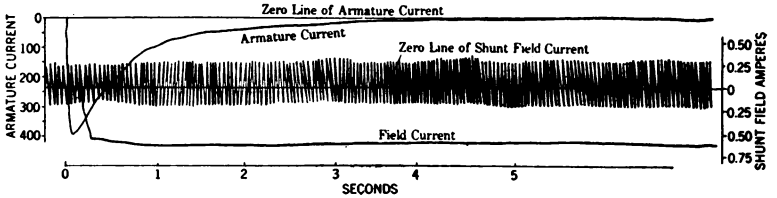


FIG. 9—STARTING TESTS ON 7½-H. P.—230-VOLT—1150-REV. PER MIN.—COMPOUND MOTOR

Shunt field—self excited—no-load condition—130 lb. flywheel effect.

proportional to $\int i\,dt$ and the energy stored in the revolving parts is proportional to the square of the speed, and therefore to the square of the voltage.

The coefficients of the auxiliary cubic are in general positive and it has therefore no real positive root, having no changes of

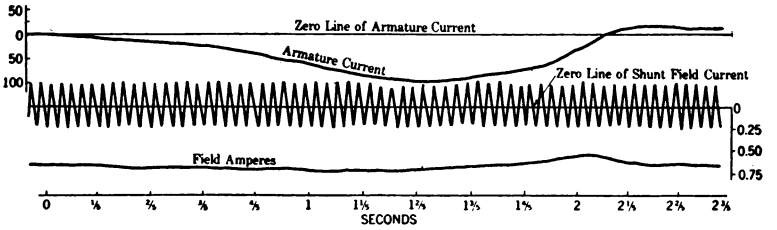


FIG. 10—STARTING TESTS ON 7½-H. P.—230-VOLT—1150-REV. PER MIN.—COMPOUND MOTOR

Shunt field excited separate 230-volt source—no series field in no-load condition—35 lb. flywheel effect.

sign. It has always one root of sign opposite that of the last term that is negative. The remaining two may be negative or imaginary. In case of a pair of imaginary roots, two of the terms would appear in the form

$$A_1\,\epsilon^{-a+j\beta} + A_2\,\epsilon^{-a-j\beta}$$

From the relations existing between the exponential and trigonometric functions these terms can be written

$$\epsilon^{-a}\,(B_1 \cos\,\beta + B_2 \sin\,\beta)$$

Digitized by Google

That is, speed and current will oscillate slightly about their normal values, but will quickly settle if a constant flux is maintained. If, however, the compensating field is not strong enough to keep the flux from decreasing with load, and the resistance drop not sufficient to offset the decrease in flux, the motor has a rising speed curve. With the moment of inertia exceeding a certain value under these conditions, the current and speed will continue to oscillate and the operation is unstable. The oscillograms in Fig. 10 were taken without the series field in the circuit and the unstable condition is plainly shown. The current rises to approximately 100 amperes then decreases and reverses reaching approximately 25 amperes in the opposite direction,

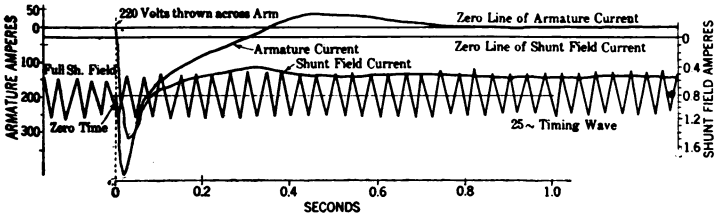


FIG. 11—STARTING TESTS ON 7½-H. P.—230-VOLT—1150-REV. PER MIN.—COMPOUND MOTOR

No-load condition—pulley removed—series field removed—shunt field excited to 230 volts separate source—220 volts applied to armature.

repeating the cycle about every 3 seconds. The speed rises to approximately 20 per cent above normal.

The oscillograms in Fig. 11 were also taken with the series field left out. In this case the flux decreases with increasing armature current and the direction of the voltage generated in the field winding is such as to increase the field current instead of decreasing it. It will be noticed that the field current rose momentarily to almost three times its normal value. It is interesting to note the effect of this on the armature current and the acceleration. The armature current decreases rapidly until the shunt field has fallen to its normal value when the weakening of the field is shown by the sharp bend in the armature current curve.

Digitized by Google

Digitized by Google

To be presented at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 14, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

EFFECT OF CURRENT LIMITING REACTORS ON TURBO-GENERATOR SYSTEMS UNDER CONDITIONS OF SHORT CIRCUIT

BY P. B. JUHNKE

ABSTRACT OF PAPER

An account of a cable breakdown near one of the generating stations of the Commonwealth Edison Company's system. The breakdown resulted in a second breakdown on same line within the station, which prevented the oil switch from automatically disconnecting the fault. The system is amply protected by reactors for generators and between bus sections. Their effect on the stability of synchronous apparatus on sections protected by them is very marked. The protection to generating station apparatus was complete. Comparison of maximum stresses encountered in the short circuit as it occurred with what they might have been without reactors present are made, and the conclusion is drawn that without them the damage resulting would have been considerable and the service interruption far more general and serious.

WHILE current-limiting reactors are by no means of recent date, having long passed the experimental stage, comparatively little data are available showing in what manner they perform their intended functions under conditions of short circuit on systems protected by them. This paper contains an account of a cable breakdown near the generating station, which resulted in a second failure on the same line within the station, between the current transformer and the automatic oil switch, thereby preventing immediate operation of the latter. As the system in question is one of the largest in the country, amply protected by reactors on the generators and between sections of the bus, an analysis of the effect of the short circuit on the system might not be without interest.

EVENTS BEFORE AND DURING TROUBLE

The system in question is that of the Commonwealth Edison Company. The breakdown in question occurred at the Quarry St. station on line No. 223, December 22, 1916, 7:31 p.m. Its first indications were the tremendous roar of the generators,

Manuscript of this paper was received January 23, 1917.

Digitized by Google

the violent swinging of all tie-line and transmission-line ammeters, the automatic opening of the switches on the 5000-kw. frequency changer, which tied the 25 and 60-cycle systems, and the automatic opening of lines 212, 213, and 226. After a period of about 10 to 15 seconds, the automatic opening of line switch No. 223 cleared the trouble.

When the short circuit had cleared itself, about 80,000 kw. of system load had been automatically disconnected by the operation of the protective devices in the sub-station. This resulted in a rise of the system frequency, which caused three of the four Quarry generators to trip out on the steam end.

An investigation revealed the fact that the connector between oil-switch leads and current transformers on *B* and *C* phases of line No. 223 as shown in Fig. 1, had burned off and that one of the leads had established an arc to a ground bus and the other to a bolt embedded in concrete. The arc had damaged the relay wiring on *B* and *C* phases of line No. 223, making these two relays inoperative, but leaving *A* phase relay intact. A test on the cable of line No. 223 indicated that the line had burned open on *B* and *C* phases outside of the station, and that *A* phase was grounded. The cable fault was located in the conduit on station grounds, about 600 ft. from the oil switch. About two feet of the cable was found to have been destroyed.

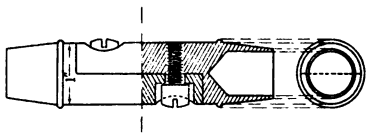


FIG. 1—CURRENT TRANSFORMER CONNECTOR

When repairs were made it was found that this burnout had occurred within a very few feet of the location of a previous burn-out on line No. 1222, which was in a diagonally adjacent duct. Nothing serious, however, was indicated by the latter burn-out. The switch had opened promptly and the cable gave no evidence of any unusually severe trouble.

When repairs on line No. 223 were made and the close proximity between this burn-out and the burn-out on line No. 1222 was established, it was thought best to dig up the conduit, break out the ducts and expose the cables to determine if any other cables had been injured. This was impossible at the moment, as the ground was covered with storage coal, and it was several days before the coal could be removed for the purpose.

On exposing the cable it was found that an adjacent duct wall had been broken and that the lead had been burned from one

Digitized by Google

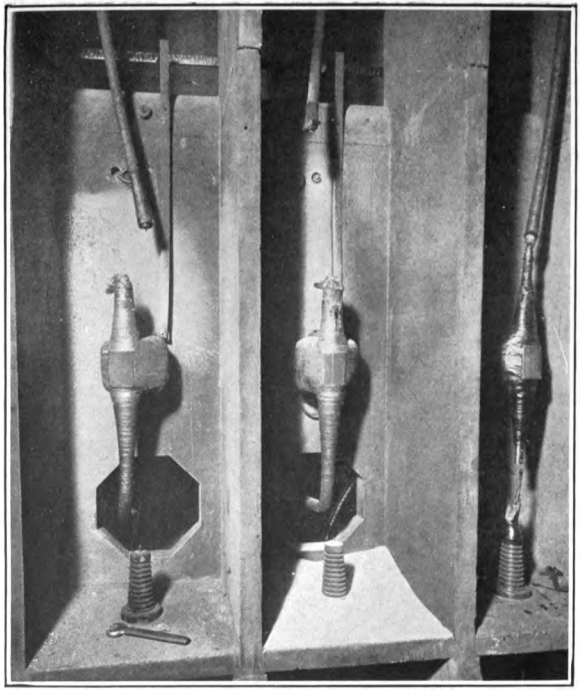


FIG. 2—BURNED OFF LINE LEADS

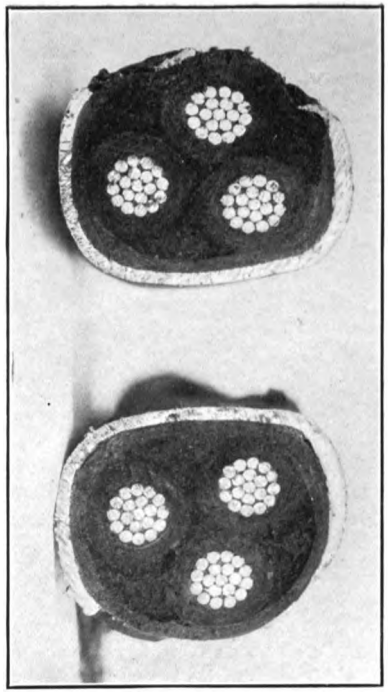


FIG. 4—SECTION OF CABLE FROM LINE 1217 AFTER REMOVAL

[JUHNKE]

FIG. 5—CABLE OF LINE 1217 AT POINT OF BURN-OUT

Digitized by Google

side of line No. 1217 in this same duct. The force of the explosion had pushed the cable of this line forcibly against one side of the duct, so that the exterior of the cable assumed very closely the form of the inside of the tile ducts. This is shown in Fig. 4, which is reproduced from a photograph of a section of this cable after removal. The external injury to this cable at the location of the burn-out is shown in Fig. 5, as it was found eight days after the trouble on line No. 223 occurred, during which time it had been in continuous operation. This line did not break down, but the cable was removed and replaced.

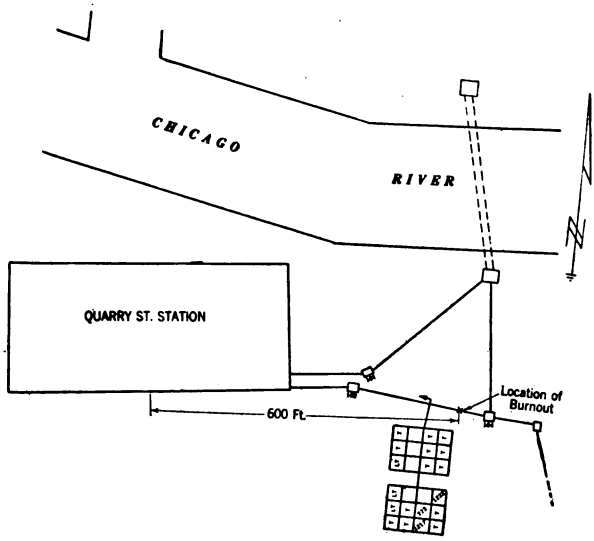


FIG. 3—PLAN SHOWING CONDUIT LOCATION AND POINTS OF BURNOUTS—QUARRY STATION PROPERTY

ANALYSIS OF SEQUENCE OF EVENTS

An analysis of the trouble led to the conclusion that the initial fault on line No. 223 occurred between *B* and *C* phases in the cable. With the lead sheath at the location of the burn-out destroyed by the previous burn-out on line No. 1222, this was the most likely failure and probably due to moisture penetrating the insulation.

It is believed that when the fault outside was established, the great rush of current, largely due to the nearness of the fault to the station bus, caused the joint between the lead from the oil switch and the current transformer to break apart on both *B*

Digitized by Google

Digitized by Google

side of line No. 1217 in this same duct. The force of the explosion had pushed the cable of this line forcibly against one side of the duct, so that the exterior of the cable assumed very closely the form of the inside of the tile ducts. This is shown in Fig. 4, which is reproduced from a photograph of a section of this cable after removal. The external injury to this cable at the location of the burn-out is shown in Fig. 5, as it was found eight days after the trouble on line No. 223 occurred, during which time it had been in continuous operation. This line did not break down, but the cable was removed and replaced.

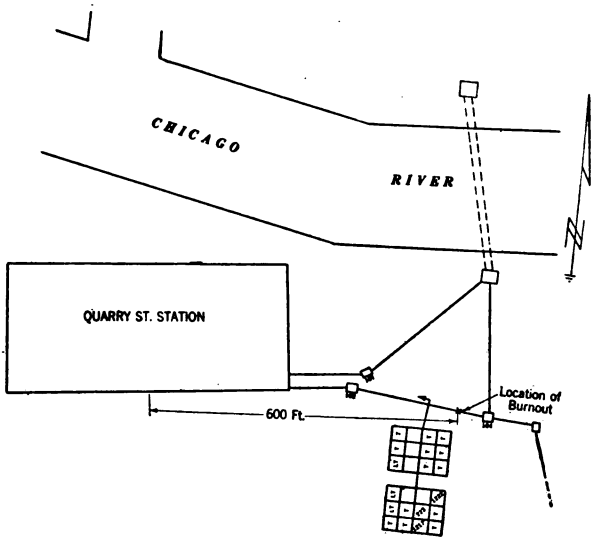


FIG. 3—PLAN SHOWING CONDUIT LOCATION AND POINTS OF BURNOUTS—QUARRY STATION PROPERTY

ANALYSIS OF SEQUENCE OF EVENTS

An analysis of the trouble led to the conclusion that the initial fault on line No. 223 occurred between *B* and *C* phases in the cable. With the lead sheath at the location of the burn-out destroyed by the previous burn-out on line No. 1222, this was the most likely failure and probably due to moisture penetrating the insulation.

It is believed that when the fault outside was established, the great rush of current, largely due to the nearness of the fault to the station bus, caused the joint between the lead from the oil switch and the current transformer to break apart on both *B*

Digitized by Google

and C phases. It is probable that when the arc to ground was established, the arc to the short-circuited cable was maintained until A phase broke down either to ground or to one of the other phases, which caused the A phase relay to open the oil switch on line No. 223, thereby clearing the trouble from the bus.

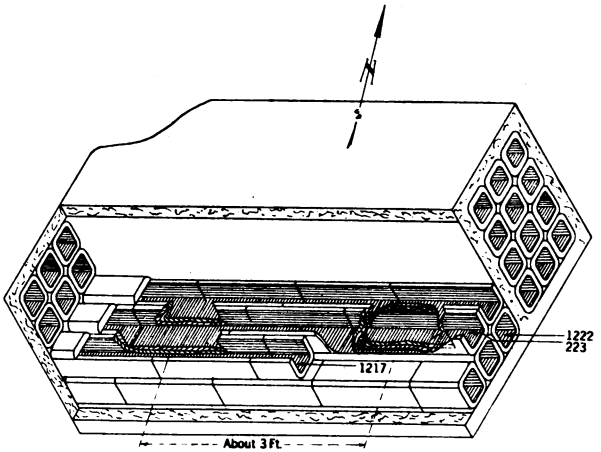


FIG. 6—SECTIONAL SKETCH OF EXPOSED CONDUIT

DESCRIPTION OF SYSTEM

The total capacity of the 25-cycle, 9000-volt system here concerned consisted of 17 generators and a 5000-kw. frequency changer of a combined capacity of 251,000 kw., each of the generators having, including its external reactance, a total reactance of approximately 8 per cent. The load carried was approximately 200,000 kw. This system, at the time of the trouble consisted of four more or less distinct parts, with generating capacity and load at time of trouble, as follows:

Station or section	Generating capacity	Number of machines	Load
Northwest	50,000 kw.	2	50,000 kw.
Fisk A. Section	60,000 "	5	48,000 "
Fisk B. Section	80,000 "	6	55,000 "
Quarry St.	61,000 "	5	49,000 "
	251,000 kw.	18	202,000 kw.

Fisk A and B sections are the two parts into which the Fisk St. station 25-cycle bus is divided, each of these two sections being separately in parallel with Quarry St. over a tie line protected by a balanced relay, and consisting of three 250,000-cir.

Digitized by Google

mil, three-conductor, 9000-volt cables of an average length of 2400 ft. In each phase of this tie line is a 20 per cent series reactor, this value being based on Y-voltage drop at the rated full load of 10,000 kv-a. per line. These three sections are thus operated on the open-ring principle. Northwest is connected with Fisk section *B* over four tie lines of a total cross section of 1,000,000 cir. mils and average length of eight miles, these tie

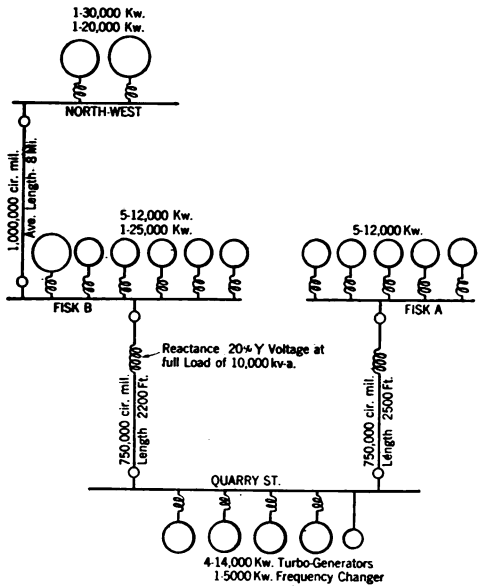


FIG. 7—DIAGRAM OF SYSTEM AS OPERATED AT TIME TROUBLE OCCURRED

lines carrying stations along their route. The relays on these tie lines are of the bellows type, with a setting on each line as follows: Minute, 9375 kv-a.; 2 seconds, 11,700 kv-a., and inst., 14,000 kv-a. Fig. 7 is a diagrammatic representation of the system as it existed at the time the trouble occurred.

At this time the synchronous apparatus supplied by the different sections was as follows:

Sections	Apparatus in substations	
	Synch. conv.	Synch. motors
Northwest	9 substations	2 substations
Fisk A Section	20 " "	3 " "
Fisk B Section	18 " "	1 " "
Quarry St.	15 " "	1 " "

Digitized by Google

Effect of Short Circuit on System

At the time the trouble occurred, nearly all the synchronous apparatus feeding from Quarry St. lines was automatically disconnected, about 70 per cent through operation of a-c. overload relays opening oil switches, apparently due to back feed into the short circuit; about 28 per cent due to reverse current or low-voltage release relays tripping d-c. circuit breakers. This ratio of apparatus disconnected by operation of oil switches to that disconnected by operation of d-c. breakers is exceedingly small in the stations supplied by either of the Fisk St. sections, while

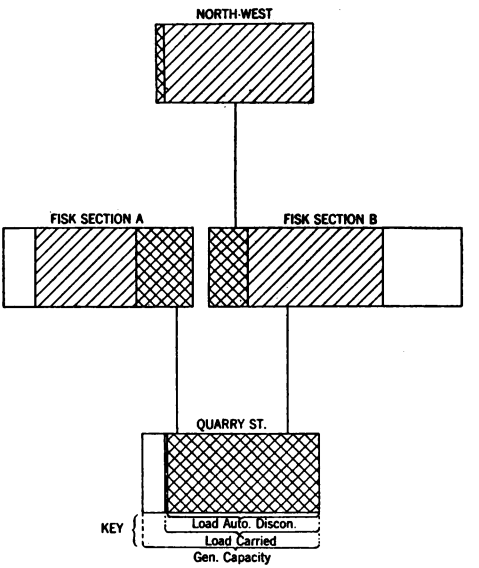


Fig. 8—Diagram of Generator Capacity—Load Carried and Load Automatically Disconnected

none of the apparatus on Northwest lines was disconnected on the a-c. side. The only machine which was automatically disconnected on the a-c. side on Fisk *B* section tripped out because it was operating in parallel on its d-c. end with a machine twice its size, feeding from Quarry St., due to the overload caused by the reversal of the latter, on which only the d-c. breakers opened. Fig. 8 is a diagram of generating capacity, load carried, and load interrupted when trouble occurred.

This diagram clearly demonstrates the beneficial effect of current-limiting section or bus reactors on the stability

Digitized by Google

of apparatus on the sections protected by them. While very nearly 100 per cent of the capacity and load supplied by the section on which the trouble occurred was affected, only 36 per cent of the load on Fisk section *A* and 27 per cent on Fisk section *B* was interrupted. Of the total Northwest load only about 6 per cent was affected. The smallness of this latter figure undoubtedly is due to the considerable amount of tie line resistance between Northwest and Fisk section *B*. The rather considerable loss in load on Fisk *A* and *B* sections was mostly due to d-c. circuit breakers opening in some of the substations supplied by *A* and *B* sections, which in a large measure was caused by overloads from the interruptions to substations which had been supplied by Quarry St. lines.

Probable Values of Short Circuit

Calculations to determine the dimensions of the short-circuit current and stresses due to them can only be approximate. The calculations presented herewith are largely based on test data contained in a paper submitted to the Institute in June, 1911, by Messrs. Schuchardt and Schweitzer. Certain assumptions, however, can be made with a fair degree of probability, which will at least permit of determining the maximum values of the current into the fault. These are:

1. That the fault in the cable was of negligible resistance (variations in the value of this quantity, if same is taken at 0.025 ohm, do not materially affect the result).

2. That the behavior of the Quarry St. machines is comparable to that of the Fisk St. machine, tests on which were reported in the paper by Messrs. Schuchardt and Schweitzer.

3. That the synchronous apparatus connected to Quarry St. at the time the trouble occurred, returned energy at a power factor of about 10 per cent for the 230-volt synchronous converters and motors, and 5 per cent for the railway converters.

Based on these assumptions, the maximum short-circuit current is made up of the following components:

A. Current supplied by the Quarry St. generators.

B. Current supplied by the Fisk St. generators, over tie lines *A* and *B*.

C. Current supplied by synchronous apparatus directly connected to Quarry St. lines.

This is determined by taking the short-circuit currents of the three parts and combining them vectorially. This gives the

Digitized by Google

combined impedance, to which then is added the impedance of the faulty line, giving the resultant short-circuit impedance.

The calculation is carried out in detail for the Quarry St. machines as follows:

Maximum short circuit between phases on four 14,000-kw. turbo-generators = 4 × 900 × 11.9 = 42,840 amperes, at a generator open-circuit voltage of 9000 volts.

Total maximum effective short-circuit current = 49,240 amperes.

Generator open-circuit voltage corresponding to excitation with load carried before trouble occurred = 10,200 volts.

$$\text{Impedance of armature circuit} = \frac{10{,}200}{49{,}240} = 0.206 \text{ ohm.}$$

Power factor taken as 7 per cent, which is the probable figure given in the paper previously mentioned.

Resistance of armature circuit = 0.07 × 0.206 = 0.014 ohm.

Reactance of armature circuit = 0.205 ohm.

Maximum effective short-circuit current = 45,800 amperes.

Power factor = 7 per cent.

In like manner the combined Fisk A and Fisk B section current, limited almost entirely by the sectionalizing reactors, can be shown to be..... 5,800 amperes.

Power factor = 2.8 per cent.

Short-Circuit Current of Synchronous Apparatus

This calculation assumes approximately 5 × full-load current for railway machines and 20 × full-load current for the 230-volt converters and the frequency changers.

Total capacity of railway machines connected to Quarry St.....	42,000 kw.
Total capacity of 230-volt converters and frequency changers connected to Quarry St.....	17,100 "
Maximum effective short-circuit current of railway machines at power factor 24.7 per cent.....	11,500 amperes.
Maximum effective short-circuit current of 230-volt converters and frequency changers at power factor 54.5 per cent...	11,800 "

Digitized by Google

Total maximum effective short-circuit current supplied by synchronous apparatus at power factor 40.6 per cent.....	23,000 amperse
Total maximum effective short-circuit current of Quarry St. generators, Fisk A and B Section generators, and synchronous apparatus connected to Quarry St.....	73,300 "
Power factor = 17 per cent.	
Combined armature impedance=	0.14 ohm.
" " resistance = ...	0.024 "
" " reactance = ...	0.138 "
Impedance of line No. 223 to fault, neglecting resistance of arc = ...	0.062 "
Resistance of line No. 223 to fault = ...	0.06 "
Reactance " " " " " = ...	0.018 "
Total resistance of armature and line = ...	0.084 "
" reactance " " " " = ...	0.156 "
" impedance " " " " = ...	0.176 "
Power factor of circuit = 48 per cent.	
Maximum effective short-circuit current into fault, added vectorially = ...	58,000 amperes
Maximum effective value of energy in arc at a resistance of 0.025 ohm = ...	74,100 kw.

It might be of interest to compare this with the value of current that would have obtained under similar conditions had the system been without reactors in the generators and between sections of the bus. In this event the total short-circuit current, computed in same manner as with the reactors in circuit, would have been approximately 106,000 amperes, and the power factor 83 per cent. This would have multiplied the stresses incidental to the short circuit as it occurred by 3.3 and would have given stresses of approximately 1,140 lbs. per foot of parallel conductors below oil switch. Such stresses more than likely would have damaged the bus structure, would have immensely increased the task of oil switches and made the service interruption far more extensive and serious.

Behavior of Sub-Stations.

While synchronous apparatus in a number of substations was automatically disconnected through operation of either the a-c. or d-c. relays, the interruptions in the substations so affected

Digitized by Google

were of remarkably short duration and the recovery was exceedingly rapid. As nearly as can be determined, the service interrupted from substations connected to the section in trouble amounted to about 50,000 kw. for five minutes, on one of the two sections protected by sectionalizing reactors to about 20,000 kw. for three minutes, and on the other to about 10,000 kw. for two minutes. The behavior of sub-station protective devices during the trouble is a subject full of interest, the complete analysis of which, however, has not yet been completed.

Conclusion.

Considering results in their entirety, the influence of the reactors must be pronounced as exceedingly beneficial. Not a single piece of generating station apparatus was disabled, as was almost invariably the case before the installation of current limiting reactors. Even on the section directly affected everything was ready for immediate resumption of service as soon as the trouble was cleared. The value of the reactors seems to have been happily chosen; no evil results attended the operation of the system during and after the trouble; no oil switches failed; and, most important of all, comparatively little load was interrupted on the sections protected by the sectionalizing reactors.

Digitized by Google

Presented at the Toronto Section Meeting of the American Institute of Electrical Engineers, September 22, 1916.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions*)

ELECTRICAL MACHINERY TESTS AND SPECIFICATIONS BASED ON MODERN STANDARDS

BY H. M. HOBART

ABSTRACT OF PAPER

Comparisons are made of the standardization rules for electrical machinery now in force in various countries. It is shown that the differences are of a very minor character and that machinery built in conformance with the American rules will usually also conform with the rules employed in other countries. The suggestion is made that 55 degrees could be employed as the ambient temperature of reference for tropical ratings and it is maintained that such a plan fits in nicely with the value of 40 degrees already adopted as the ambient temperature of reference for other than tropical ratings. Attention is called to a series of acceptance tests on some large waterwheel generators and to the temperature results obtained by making cyclic heat runs on these machines.

IN THE course of his work the author frequently has been brought face to face with the fact that the mere drafting and circulating of standardization rules constituting a radical departure from former practise, are insufficient to bring about general use of the contemplated modifications. It is necessary to have a wide and thorough discussion in order that there shall be a clear appreciation of the reasons for and the consequences of the alterations. Furthermore, in working out so comprehensive a proposition as that represented by the Standardization Rules of the American Institute of Electrical Engineers, provision has to be made for a large number of details, whose importance, if not especially emphasized, is liable to be overlooked in the practical application of the rules to concrete cases. There are a good many sections in the rules, which at first glance would seem of minor importance, but which, nevertheless, set forth requirements which cannot be disregarded advisedly on the occasions of acceptance tests and in the drafting of specifications.

The author recently has had occasion to carry out a series of very interesting acceptance tests upon some large waterwheel-driven generators. Since it was the purpose to make the tests with exceptional care, it seemed to be an admirable occasion to

Manuscript of this paper was received November 6, 1916.

Digitized by Google

subject the American rules to a thorough test. Consequently especial endeavors were made to conform with the requirements set forth in the American rules. Various points arose in which this practical process of putting the rules to the test, suggested the desirability of slight modifications to increase their definiteness.

In the original drafting of a specification, the feasibility of determining by simple tests that the requirements of the specification have been fulfilled, should always be kept prominently in mind. Indeed the close association between a consideration of the terms of the specification and a consideration of the general subject of the carrying out of acceptance tests is so obvious that it is unnecessary to further justify the predominance given in this paper to the acceptance-tests aspects of the subject.

As regards electrical machinery, the British Standardization Rules issued by The Engineering Standards Committee in Report No. 72 and the October, 1916 edition of the Standardization Rules of the American Institute of Electrical Engineers are in such close agreement that machinery built and rated to conform with the one set of rules will usually also conform with the other set of rules. The slight quantitative differences between the two sets of rules practically always will be covered by the margin reserved by manufacturers. This general statement of fact is made as a matter of interest, but of course it is always important to make certain that the standardization rules according to which the machinery is specified in any particular case agree in all particulars. An appendix to this paper contains in tabular form a statement showing the slight differences in the temperature limits in the British and American standardization rules. The heating and temperature sections of the 1916 edition of the Italian rules are also in close agreement with the corresponding sections of the British and American rules.[1]

The British rules do not yet cover quite as many subjects as the American and Italian rules, which already comprise sections relating to efficiency and to regulation in addition to those covered by all three sets of rules. The limitations of this paper will not permit of a discussion of these two latter subjects nor of the subject of dielectric tests, notwithstanding their interest and importance. The paper is further limited chiefly to points relat-

1. "Standards for the Ordering and Acceptance of Electrical Machines" issued by the Italian Electrotechnical Association; Central Offices: 10 Via S. Paolo, Milan.

Digitized by Google

ing to rotating machinery, the important subject of stationary transformers being excluded since its consideration would have too greatly increased the length of the paper.

Temperature Standards

So far as relates to heating and temperature, the plan underlying all modern standardization rules for electrical machinery consists in establishing approved upper limits of temperature. These limits are such as to permit of continuous subjection thereto. While as an actual fact these limiting temperatures could be exceeded safely for short intervals, this is not permitted by the rules. The approved upper limits have been determined upon with a view to providing adequate factors of safety. Having determined upon approved values for the upper temperature limits, the next step consists in adopting a reference value for the ambient temperature. The difference between the approved upper limits and the ambient temperature of reference constitutes the limiting temperature rise. The *rating* is obviously a function of the thus-deduced temperature rise.

Ambient Temperature of Reference

In the British, the American and the Italian rules the ambient temperature of reference is 40 deg.[2] This value is adopted because it is a temperature approached in all parts of the temperate zone at some time during the year.

In none of these three sets of rules is there, as yet, any provision for machinery for tropical countries. The author would suggest 55 deg. as a suitable ambient temperature of reference for tropical ratings. The suggestion is not based on any contention that electrical machinery is liable to be installed in locations where an ambient temperature of 55 deg. would be at all likely to occur, but for the three following reasons:

First, that it is desirable to employ a value which will ensure a margin of a few degrees; *second*, that the ambient temperature of reference for tropical ratings should not exceed that for temperate ratings by less than 15 deg. (a less difference would lead to ratings which would be so nearly the same for the two cases that the difference hardly would be worth taking into account); *third*, that the value of 40 deg. is, strictly speaking, rather too low for the temperate zone. While its occurrence is by no means usual, it is so often approached within a few degrees that it

2. Throughout the paper, all temperatures are given in the centigrade scale.

Digitized by Google

cannot be said to provide much margin when employed as a standard reference value. Since 40 deg. is now firmly established for the temperate zone, the consistent value for a basis for tropical ratings is 55 deg. Practical experience has demonstrated the importance of employing distinctly lower ratings for electrical machinery destined for use in tropical countries, than ratings which have proven satisfactory for the temperate zone.

The ambient temperature of reference of 40 deg. for all countries in the temperate zone was adopted only after very careful investigations. While there are many localities where an outdoor shade temperature of 40 deg. is never attained at any time in the year, nevertheless there are in the temperate zone very few localities where an outdoor shade temperature of 35 deg. is not sometimes closely approached. It was decided that 35 deg. did not afford sufficient margin. The following data bears out the correctness of this decision.

From the report of the chief of the Weather Bureau have been taken the following maximum temperatures recorded in any station in the designated states during the year 1908.

42 deg.	Kansas, Nebraska, New Mexico, Oklahoma
43 "	Montana, Idaho, Oregon, South Dakota, Utah, Wyoming
44 "	Washington
46 "	Texas
47 "	Nevada
49 "	California
52 "	Arizona

In America, meteorological observations are often made by amateur volunteers and it is possible that some of these higher values may not have been adequately verified.

From "Symons Meteorological Magazine" for 1912 has been compiled the following table of temperatures at 20 places in the British Empire. The records consulted were compiled from 30 places in the British Empire. For the remaining ten places 32.5 deg. was not reached at any time during the year 1911.

It is of importance to emphasize that it is not essential to be able to reconcile the ambient temperature of reference with the maximum temperature occurring in the locality where the machinery is to operate. The greater the amount by which the ambient temperature of reference exceeds the temperature where the machinery is operated, the greater is the factor of safety. The shade temperatures set forth in meteorological records are usually taken where there is no local source of generation of heat and where air circulates freely. Electrical machinery in operation

Digitized by Google

itself constitutes a source of heat and increases the temperature of the surrounding air. Furthermore electrical machinery is often located in places where the circulation of air is very much restricted. Consequently the ambient temperatures near electrical machinery will generally considerably exceed the shade temperatures recorded by meteorological stations. Indeed there is no proof that the actual ambient temperatures in the neighborhood of electrical machinery are related at all closely to the official temperatures issued from meteorological stations. It is evident from the tables which have been given that, strictly speaking, even 40 deg. is too low for the reference temperature,

NUMBER OF MONTHS DURING 1911 IN WHICH THE MAXIMUM SHADE TEMPERATURE EQUALLED OR EXCEEDED:

	32.5 deg.	35 deg.	37.5 deg.	40 deg.
London	3	1	0	0
Malta	1	0	0	0
Lagos	4	0	0	0
Cape Town	3	3	1	0
Durban (Natal)	3	1	0	0
Calcutta	9	4	2	0
Bombay	9	0	0	0
Madras	8	8	6	3
Colombo (Ceylon)	4	0	0	0
Hongkong	3	0	0	0
Sidney	3	2	2	0
Melbourne	4	3	3	2
Adelaide	6	6	5	2
Perth	4	4	3	2
Coolgardie	6	6	6	5
Hobart (Tasmania)	2	2	1	0
Jamaica (Kingston)	9	3	0	0
Toronto	1	0	0	0
Fredericton	1	1	0	0
Blomfontein	5	2	0	0

on the basis that it is to be a value that shall *never* be even *slightly* exceeded. The reference value adopted must rest upon an assumption and it is important that the assumption shall be conservative. In the rules of the Verband Deutscher Elektrotechniker the ambient temperature of reference is 35 deg. The precise statement in this respect as set forth in the V. D. E. rules is as follows:

"It is assumed that the temperature of the surrounding air will not exceed 35 deg."

In the British, American and Italian rules, it is assumed that the temperature of the surrounding air will not exceed 40 degs. It is probable that in the neighborhood of electrical machinery,

Digitized by Google

i. e., at a distance of 1 to 2 meters from the machine, as set forth in Section 314 of the American rules), the temperature of the air at some time during the year exceeds 35 deg. in the majority of cases and there is often a considerable probability that the ambient temperature near electrical machinery will occasionally rise a few degrees above 40 deg. But by the adoption of 40 deg. as the ambient temperature of reference there will for almost all installations of electrical machinery in the temperate zone probably be a margin of a few degrees during 99 per cent of the year. For such an indefinite state of affairs, it is reasonable to adopt a value which offers some probability that there will be such a margin. It is not possible to predict the maximum ambient temperature in the neighborhood of an electrical machine within several degrees even when the machine is not running, and the value to which the ambient temperature is likely to attain when the machine is in operation is still more indefinite. The records of the official shade temperature for any given locality are of little or no service. Indeed the temperatures maintained within buildings are apt to be fully as high in cold climates as in warm climates. In view of the indefiniteness inherent to the subject, and of the importance of taking a conservative value, it would appear that the reference value of 40 deg. for the ambient temperature in regions in temperate climates is certainly not too high and reasonably might be criticized as too low. From whatever way the matter is approached there is obviously a 5-degree-greater factor of safety, (in other words, a more conservatively rated machine), when the rating is based on an ambient temperature of reference of 40 deg., as in the British, Italian and American rules, than by basing it on 35 deg.

A distinct commercial value attaches to the provision of means for maintaining at a reasonably low temperature the premises in which electrical machinery is operated. If a temperature of 30 deg. on these premises is never exceeded at any time during the year, then the maximum temperature ever occasioned in the electrical machinery when operating at its rated load is 10 deg. below the approved limits and the margin of safety is very much greater.

The Ambient Temperature During Acceptance Tests

In determining the ambient temperature on the occasion of acceptance tests in the case of rotating machines cooled by

Digitized by Google

forced draft, it is provided in Section 311 of the American rules that "a conventional weighted mean should be employed, a weight of *four* being given to the temperature of the circulating air supplied through ducts and a weight of *one* to the surrounding room air." Thus, for example, if, on the occasion of an acceptance test, the circulating air is taken from outside the building and has a temperature of 14.0 deg. at the intake of the machine, while the temperature of the air in the room is 24.0 deg., the ambient temperature, from which the temperature rise is determined, should be taken as:

$$\frac{4 \times 14.0 + 1 \times 24.0}{5} = 16.0 \text{ deg.}$$

If the temperature of the machine at the end of the heat run is 70 deg., then we have:

Temperature rise *in accordance with the American rules*
= 70 — 16 = 54 deg.

Temperature rise *above room temperature*
= 70 — 24 = 46 deg.

Temperature rise *above inlet temperature*
= 70 — 14 = 56 deg.

While, strictly speaking, the weights given for the two air temperatures should depend upon the characteristics of the particular machine under test, the correction is of such moderate amount that it has been desirable in the interests of simplicity and definiteness to standardize the weighting of the two temperatures.

It is further to be noted (from Sections 314 and 315) that the room temperature is to be taken as the mean of "several thermometers placed at different points around and half way up the machine, at a distance of one to two meters," and that the value to be employed shall be the mean of the readings of these thermometers taken at equal intervals of time during the last quarter of the duration of the test.

The temperature of a large machine will not at all promptly follow the changes which are always taking place in the temperature of the premises where a heat run is being made. Consequently, if no appropriate provision be made, a greater temperature rise will usually be recorded if the heat run concludes shortly after midnight, when the air temperature in a large factory building is usually falling, than if the heat run is con-

Digitized by Google

cluded in the middle of the forenoon, when the air temperature of such a building is usually rising. Errors from this source are decreased by complying with the requirement in Section 316 that "the thermometer for determining the ambient temperature shall be immersed in a suitable liquid, such as oil, in a suitable heavy metal cup." With a falling room temperature, a mercury thermometer exposed to the room air might read at least a couple of degrees lower than an identical thermometer with its bulb immersed in oil in one of these metal cups.

To those who have not had extensive experience in testing large generators, these various precautions may seem trivial. As a matter of fact they ensure immunity from errors which may easily amount to several degrees difference in the result obtained for the temperature rise.

The British, Italian and American rules are now in agreement in providing that for rotating machinery no correction is to be made in the temperature rise on account of the particular value of the ambient temperature on the occasion of the test. The British and American rules simply suggest, (Section 320 of the American rules), that "tests should be conducted at ambient temperatures not lower than 15 deg." The corresponding Italian rule is as follows:

"For ambient temperatures lower than 40 deg. during the tests, no correction shall be applied to the results of the measurements so long as the temperature does not fall below 10 deg.; however it is not convenient that tests should be carried out at temperatures below 10 deg."

This plan of omitting any corrections is a decided improvement over the old plan of applying to the observed temperature rise, a correction which was a function of the ambient temperature at the time of the test. Careful tests have shown that the temperature rise of the average machine is not very dependent upon the temperature at the time of the test and that the reliability of the result cannot be increased by means of any simple corrections. Elaborate tests have been made with the object of clearing up this matter by making heat runs in a room maintained successively at low and high temperatures. The rise with low room temperatures averaged as great as the rise with high room temperatures, the inverse change in core and copper loss with change in temperature combined with the very rapid increase in radiation at high temperatures tending to render the result independent of the room temperature.

Another progressive ruling which is identical in the British

Digitized by Google

and American rules is that relating to the duration of heat runs. It is to the effect that:

"The temperature test shall be continued until sufficient evidence is available to show that the maximum temperature and temperature rise would not exceed the requirements of the rules, if the test were prolonged until a steady final temperature were reached."

For conditions where the temperature of a part cannot be obtained until the machine is shut down, (for example, the resistance of the stator windings of a polyphase generator), the rules make the following provision:

"Whenever a sufficient time has elapsed between the instant of shut-down and the time of the final temperature measurement, to permit the temperature to fall, suitable corrections shall be applied, so as to obtain as nearly as practicable the temperature at the instant of shut-down. This can sometimes be approximately effected by plotting a curve, with temperature readings as ordinates and time as abscissas, and extrapolating back to the instant of shut-down. In other instances, acceptable correction factors can be applied."

As to these *acceptable correction factors*, it may be said that from the many test results available on the records of manufacturers, it will be known generally that, for a particular type of machine, the cooling of the hottest-spot will be approximately at some particular rate per minute for the average of the first three or four minutes after shut-down. At the time of the acceptance tests, both parties to the transaction usually will readily arrive at a satisfactory agreement that for any particular machine under test a certain number of degrees shall be added to the temperature determined by resistance measurements made within a given number of minutes of shut-down. It rarely would be worth while to encumber the specifications and guarantees with a clause setting forth the amount of this correction, but it is simple enough to do so when it is considered that it is of sufficient consequence to have the amount definitely stipulated.

Embedded Temperature Detectors

The American rules (Section 355) require that for the purposes of acceptance tests, the temperatures of the stators of large generators shall be determined by means of embedded temperature detectors, several of which shall be employed. These are to be so located as to disclose as nearly as possible the temperature of the hottest spot existing anywhere in the machine. These embedded temperature detectors consist of thermo-couples or resistance coils. An extensively employed design of embedded

Digitized by Google

temperature detector of the resistance type, has a length of about 10 in. (25.4 cm.), and, at a temperature of 25 deg., its resistance is just 10 ohms. In Fig. 1 are shown sections through slots for two types of slot windings usually respectively designated two-layer and single-layer windings. It is required in Sections 353 and 354 of the American rules that "a liberal number" of temperature detectors shall be placed in the locations designated in Fig. 1 as *A* and *B*, for two-layer windings, and *B* and *C* for one-layer windings.

The Hottest-Spot Temperature

The rules stipulate that for machines with two-layer windings, the hottest-spot temperature shall be considered to be 5 deg. greater than the highest reading obtained by any of the embedded temperature detectors; and that in single-layer windings the hottest spot temperature shall be that obtained by adding to the highest reading 10 deg., plus 1 deg. per 1000 volts above 5000 volts of terminal pressure.

These corrections are brought together in the following table:

For two-layer windings.	Add 5 degrees to the highest reading.
For single-layer windings for 5000 volts or less.	Add 10 degrees to the highest reading.
For single-layer windings for more than 5000 volts.	Add to the highest reading 10 deg., plus 1 deg. for every kilovolt by which the voltage between the terminals of the machine exceeds 5 kv.

Thus for a three-phase machine with an 11,000-volt single-layer winding, the correction to be added to the maximum observable temperature in estimating the hottest-spot temperature, is 16 deg.

Usually the hottest-spot results derived from the indications of the embedded temperature detectors are the most satisfactory. It is, however, quite possible that the temperature rise derived from measurements of the resistance of the stator windings at the conclusion of the heat runs sometimes may be greater than the temperature rise determined from the embedded detectors. Consequently it is provided in Section 352 of the American rules that when the embedded-detector method is used, the results shall, *when required*, be checked by the results obtained from measurements of the resistance of the stator windings, and "the hottest-spot shall then be taken to be the highest value by either method, the required correction factors being applied in

Digitized by Google

each case." By correction factor is meant the number of degrees which shall be added to the observed temperature to obtain the hottest-spot temperature. For the resistance method the correction factor is 10 deg.

As regards the so-called correction factors[3] established in the American rules, it would appear that the hottest-spot temperature determined by adding to the observable temperature the *stipulated* correction factor shall constitute the criterion and that a machine could not be rejected on the ground that other evidence demonstrated that a still-greater temperature existed at some point of the winding. For example, for purely research purposes it would be practicable to locate temperature detectors

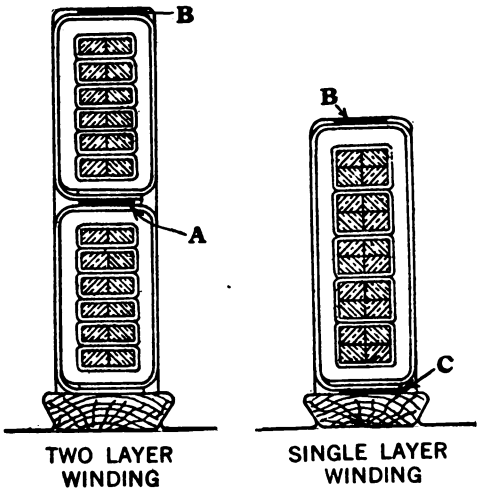


FIG. 1

actually against the copper of a high-pressure winding. In some special cases such temperature detectors might disclose temperatures exceeding those obtained by adding the conventional correction factors to the observable temperatures. Since the conventional correction factors have been established with every intention that they shall be liberal and since definiteness in contracts is essential, the hottest-spot temperatures obtained by complying with the methods approved in the American rules should be taken as final, irrespective of evidence of the existence of higher temperatures. It is believed that it would be only in exceedingly rare instances that higher temperatures could be

3. These are not factors. Some better designation should be substituted.

Digitized by Google

found and that they would exceed the conventional hottest-spot temperatures by immaterial amounts. However, in so far as the rules on this point may be obscure in the least, it would seem to be very important to make their intention unmistakably evident.

The use of embedded temperature detectors has been demonstrated to be of great advantage. When only required for the acceptance tests the leads from the detectors may, at the conclusion of the tests, be cut off, and the detectors abandoned. But it is of decided advantage, in the service operation of large generators, to be able, at any time, to ascertain the internal temperatures from the direct readings of switchboard instruments. This practise is now very customary.

It has been mentioned that the hottest-spot temperatures indicated by embedded detectors may in rare instances be less than the hottest-spot temperatures indicated by measurements of the resistance of the stator winding of a generator. Moreover since the resistance measurements of a winding only disclose *average* temperatures, occasions will arise where a suitably-located surface thermometer may indicate a temperature in excess of that indicated by the resistance measurements. A liberal number of surface thermometers ought, therefore, also to be employed when making heat runs. The author of the present paper is of the opinion that one of the chief advantages of embedded temperature detectors of the resistance type relates to the ability to employ a resistance of a magnitude which can be measured readily with accuracy, and to the reliability with which its resistance at any time can be taken to indicate a definite temperature. The temperature rise obtained from the increase in the resistance of an armature or field winding would be of distinctly greater value were it practicable to know accurately the temperature of the winding on the occasion of the measurement of the cold resistance. It is rarely parcticable to incur the delay before commencing a heat run, which would be necessary to ensure that an armature or field winding is within a couple of degrees of the surrounding temperature. Often when it is assumed that the winding's temperature is substantially identical with that of the surrounding air, there is actually a difference of over five degrees and consequently the measured cold resistance is associated with a temperature over five degrees different from its actual temperature and a corresponding error is incurred in deducing from its hot resistance the temperature of the winding at the end of the heat run.

Digitized by Google

Some such plan as that set forth in the following clause, if the conditions of practise should permit of its adoption, would provide a way out of the difficulty and much increase the value of temperature determinations by measurements of the resistance of the main windings:

"In order to avoid protracted delays in the testing of a machine, in bringing the temperature of its windings into accord with the ambient temperatures, the resistance of the windings of a machine, reduced to 40 deg., should be made a matter of factory record for all machines subject to temperature measurement by resistance under these rules."

In general, the author's opinion in this matter is that the methods of obtaining temperatures by surface thermometers and by measurements of the resistances of the main windings should not be discarded in favor of the newer method by embedded temperature detectors, but should continue to be employed *in addition thereto*. Indeed the careful tests made on a large machine, which are described later, showed, as may be seen from the last Table in the paper proper, that in two out of the three heat runs, the temperature rise of the hottest spot as deduced from measurements of the resistance of the stator windings was greater than the temperature rise of the hottest spot deduced from the readings of temperature detectors, and that in the third heat run the temperature rise of the hottest spot was the same by both methods. Furthermore the readings of mercury thermometers placed against appropriate parts of the surface of the rotor winding disclosed higher temperatures than were obtained by means of measurements of the resistance of the rotor winding. The results in these tests were especially reliable since the cold resistances were measured with the greatest care after the machine had been standing idle for two days, so that its windings at the time of measuring their resistances before beginning the heat run, should be at the same temperature as the surrounding air.

A recommendation to take advantage of all three methods, that is to say, Method I, surface thermometers, Method II, main-winding resistance measurements, and Method III, embedded detectors, might at first sight be condemned as impracticable on all except large, valuable machines, on the ground that the expense of making such thorough tests would be prohibitive. Were it necessary to make these measurements on each and every machine, such a criticism would be well founded. But the author of this paper holds the opinion which, in another publication, he has expressed as follows:

Digitized by Google

"Although the rules contain no explicit statement to that effect, it may doubtless be understood that it is not intended that a test by the prescribed method need necessarily be made upon every individual machine comprised in a transaction. The simplest method, as above explained, is usually Method I, and in the interest of avoiding needless expense, it should often be practicable to arrange for a judicious employment of Method I for most of the machines of a given size, employing Method II or III, as the case may be, on a few of the machines, and thereby arriving at a factor by which the results obtained by Method I require to be multiplied in order to arrive at the results which *would have been obtained* on those particular machines had Methods II and III been employed. In other words, it should not be concluded that the less simple measurements will necessarily be made on every machine, but rather that conclusive evidence shall be provided to insure that *had the measurements been made*, the temperature would have been within the required limits."

Further Consideration of the Hottest-Spot Temperature. The American rules lay emphasis on the hottest-spot temperature. Limiting approved values for the hottest-spot temperatures are set forth. The limiting values depend chiefly upon the class of insulating material employed. Insulating materials are divided into three classes, *A*, *B*, and *C*. These classes are defined as follows in the American and British rules:

Class of insulation	Description of insulating material
A	Cotton, silk, paper and similar materials when so treated or impregnated as to increase the thermal limit, or material permanently immersed in oil; also enamelled wire*
B	Mica, asbestos and other materials capable of resisting high temperatures, in which any Class A material or binder is used for structural purposes only, and may be destroyed without impairing† the insulating or mechanical qualities of the insulation.
C	Fireproof and refractory materials, such as pure mica, porcelain, quartz, etc.

*For cotton, silk, paper and similar material, when not treated, impregnated or immersed in oil, the highest temperatures shall be 10 deg. lower than the limits given above for Class A.

†The word impair is here used in the sense of causing any change which would disqualify the insulation for continuous service.

No limit is placed upon the temperature of Class C insulation. The permissible temperatures and temperature rises of electrical

Digitized by Google

machinery at present are based chiefly upon the characteristics of Class A and Class B insulations. The British and American rules agree in adopting 105 deg. and 125 deg. for the limiting hottest-spot temperatures for these two classes of insulations. The author believes that it may be of some interest for him to state that he shares with many other engineers, the opinion, based on extensive tests, that 105 deg. for Class A insulations and 150 deg. for Class B insulations are both thoroughly conservative limits, when all the designing and manufacturing processes are carried out with due regard for numerous important details. But, failing the availability and application of skill and experience, even much lower temperature limits for Class A and Class B insulations will not ensure a satisfactory product. It is difficult to see how any Standardization rules can afford the necessary assurance in this respect. The successful withstanding of acceptance tests does not necessarily constitute evidence that the insulations will endure the stipulated temperatures (and other deteriorating influences which vary from instance to instance), for a satisfactory term of years. Fortunately the manufacturer's interest in the success and reputation of his product usually affords the required assurance. Indeed there is usually a strong tendency on the part of the manufacturer to refrain from taking advantage of temperature limits of established practicability until years of study by tests on samples and on experimental machines have established beyond all reasonable doubt the appropriateness of the higher limits. It is, however, important to the industry to take advantage of higher limiting temperatures as soon as a reasonable amount of experience is gained, since this permits of reduced capital costs for machinery and rarely affects prejudicially the working costs except where the action is premature. The adoption of new limits by bodies of the standing of the British and American Standards Committees is ample proof that the evidence in the case has been carefully sifted and that the time is ripe for the modification. While the temperature limits for Class A and Class B insulations can both be safely exceeded for short periods, it is in the interests of reserving reasonable factors of safety to establish them (as is expressly emphasized in the British and American rules) as limits which shall *never* be exceeded. In the British and American rules the limit at present standardized for Class B insulations is 125 deg. but there is a well-developed opinion in America that since there is now a great deal of experience on which to base the action,

Digitized by Google

the limit for Class B insulations could with advantage be raised to 150 deg.

Intensified Aging of Insulations

Reference has been made to the impossibility of framing rules to ensure that the insulations employed have satisfactory longevity. Naturally, however, the aging of insulating materials is a matter of great importance to the manufacturer. The author has been much interested in some elaborate series of tests of this character. The point of most importance to decide is that of the temperature which can be withstood for 10 to 20 years by an insulating material. It might be supposed that subjection to super-temperatures for brief periods would permit of forming an opinion regarding the life corresponding to lower temperatures. To a certain extent brief tests for short periods at super-temperatures are useful but conclusions drawn therefrom must, at the present state of affairs, be regarded as only of the nature of very rough evidence. For some Class A insulations, values of the order shown in the following table are indicated:

Temperatures which can be withstood successfully, not only electrically but physically by approved Class A insulations:

For seconds	250 degrees
" minutes	200 "
" hours	170 "
" days	150 "
" weeks	130 "
" months	115 "
" years	105 "

A very slight modification in the composition or construction of the insulation, however, might completely disqualify it for withstanding any considerable supertemperatures, even for brief periods. Tests on various approved Class B insulations lead to values which, while quantitatively higher by a matter of some 50 deg., are qualitatively very similar.

Reasonable factors of safety must, however, be reserved. This is realized by the British, American and German Standards Committees and no recognition whatsoever is extended to the ability of insulations to successfully withstand super-temperatures for brief periods. Thus in the American rules we have Section 305 A, to the following effect:

Section 305 A. Whatever may be the ambient temperature when the machine is in service, the limits of the maximum observable temperature

Digitized by Google

and of temperature rise specified in the rules should not be exceeded in service; for, if the maximum temperature be exceeded, the insulation may be endangered, and if the rise be exceeded, the excess load may lead to injury, by exceeding limits other than those of temperature; such as commutation, stalling load and mechanical strength. For similar reasons, load in excess of the rating should not be taken from a machine.

It is thus clear that in the interest of securing a liberal margin of safety we must forego rigorously the temptation to expose the insulation of machinery, even for brief periods, to temperatures in excess of the limits approved in the American rules.

This practise is in striking contrast to that underlying the older Standardization rules which authorized higher temperatures for short periods. Probably the credit for the modern departure belongs to the German Standards Committee, which, for some years, has employed the plan of permitting overloads with the same temperature limits as for the rated load. The following clauses are from the German standardization rules:

Overloading. With the limitation that the overloads only are carried for so short a time, or only occur under such temperature conditions of the machines and transformers that the highest permissible temperatures are not thereby exceeded, machines and transformers must be capable of carrying the following overloads:

Generators Motors Synch. conv. and motor-generators Transformers	25 per cent during one-half hour
Motors Synch. conv. and motor-generators Transformers	40 per cent for 3 minutes

Section 305 A of the American rules, however, contains the restriction that "loads in excess of the rating should not be taken from the machine," lest limits other than those of temperature, such as commutation, stalling load and mechanical strength should be exceeded.

Nevertheless the American rules provide for the case where a machine is required to carry very heavy loads for brief periods. Such a case is met by giving a machine more than one rating. Thus amongst the machinery recently supplied to the Chicago, Milwaukee and St. Paul Railway are some couple of dozen 2000-kw. motor-generator sets for use in substations. These sets have the following three ratings:

Continuous rating	2000	kilowatts
Two-hour rating	3000	"
Five-minute rating	6000	"

Digitized by Google

The mechanical strength and the commutating requirements for the five-minute rating are far in excess of those for the continuous rating. But the temperature attained with the continuous rating exceeds that attained with the five-minute rating.

This plan may be employed whenever it is necessary to provide for peaks of load, as in the case, for instance, of crane motors. Knowing the typical duty cycle, we may prescribe a *short-time* rating sufficient to ensure that the motor shall have ample mechanical strength as well as sufficient margin in the matter of commutation, and that it shall not stall with the greatest load which it ever will be called upon to carry. Knowing also the average load, we may prescribe a *continuous* rating which will ensure that approved temperatures shall never be exceeded. Two ratings should suffice, a continuous rating to ensure the non-exceeding of approved temperatures and a short-time rating to ensure the required capacity for the intermittently occurring peaks of load, as regards commutation, stalling load and mechanical strength.

On the whole, while as already stated, we owe the conception of modern ratings to the German Standards Committee, the way in which the American Committee has fitted the conception to the requirements of practise, would appear to be distinctly excellent.

Low-Temperature Circulating Air

For small machines built in large quantities for stock, the ultimate destination is unknown. In normal times a motor driving a printing press in Bombay or Pekin or Moscow is about equally likely to have been built in Berlin or Manchester or Milan or Schenectady. Even if the ultimate destination may be ascertained it is not practicable to countenance departures from the strict letter of the Standardization Rules in the case of small machinery.

But for large machines worth many thousands of dollars apiece and operated under skilled supervision, it would be wasteful to forego any economic advantage compatible with sound engineering practise. As a concrete case let us assume that a large operating company is purchasing a 20,000-kv-a. generator which will be cooled by circulating through it every minute 50,000 cu. ft. (1420 cu. m.) of air taken from outside the building. In the summer, on days when the humidity is high, the circulating air's temperature, even after passing through the air washer, may sometimes be nearly 40 deg. But the nature

Digitized by Google

of the load may be such that the station's peak in summer is half of its mid-winter peak, or even much less. It may be practicable to rely on 15-deg. circulating air for the mid-winter peak. For the limiting temperature for Class A insulation, (105 deg.), this represents 90 deg. "hottest spot" rise as against 65 deg. "hottest spot" rise in the summer. By temperature coils in location A of Fig. 1, the *observable* rises are:

Summer—(105—5—40) = 60 deg.
Winter— (105—5—15) = 85 deg.

Consequently, if the machine has ample margin as regards mechanical strength and if the prime mover is adequate, advantage ought to be taken of its increased capacity in winter which would be of the order of 25 or 30 per cent.

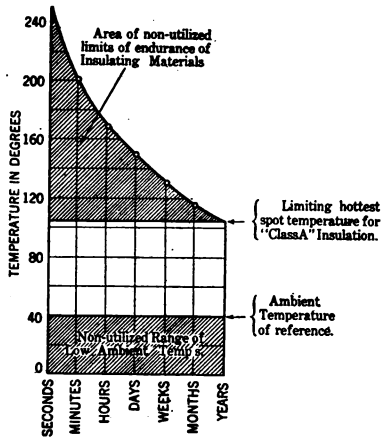


FIG. 2

Three such 20,000-kv-a. machines, operated on the basis of loading them up to their capacity as indicated by embedded temperature detectors, would do the work of four machines operated in strict accordance with Section 305 A of the American rules, and the saving in the capital component of the total cost of manufacturing electricity would be quite appreciable.

Such a case would be met by some such clause as follows:

"Contractors will be required to guarantee that the machine shall be in all respects in strict accordance with the 1916 edition of the American rules with the following exception:

Exception. The machine shall have ample mechanical strength and shall be in all other respects adequate to carry the increased load which with a circulating-air temperature of 15 deg., may be carried without occasioning hottest-spot temperatures in excess of those set forth in the American rules as approved for the class of insulation employed. For the acceptance tests, the embedded-temperature-detector method supplemented by measurements of the resistances of the main windings and by surface thermometer measurements, shall be employed for determining the temperature attained.

MARGIN OF SAFETY

Adherence to the recommendations in the British and American Standardization Rules ensure very liberal margins of safety. This is apparent from Fig. 2 in which the shaded areas indicate

Digitized by Google

respectively for machines with Class A insulation, the temperature ranges above the permitted hottest-spot temperature of 105 deg. which technically are available but which are not allowed, and the temperatures below the reference ambient temperature which are liable to exist in most locations during nearly all seasons of the year. The unshaded area represents the temperature range, utilization of which is approved in the American rules. There is no disposition to suggest encroachment upon these liberal margins of safety; they are simply in accordance with the best and most valued traditions of the engineering profession.

Equivalent Tests

We now arrive at a matter with which the Standardization Rules do not yet deal, at any rate with any approach to thoroughness. The deficiency relates to indicating the nature of the

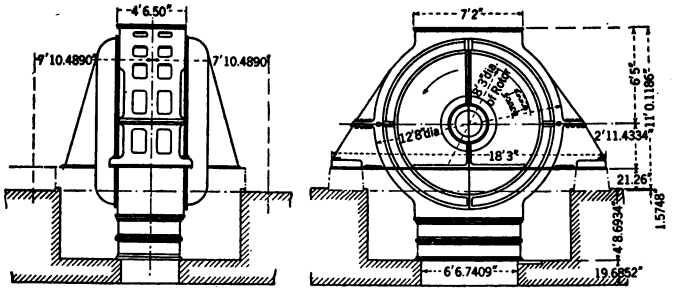


Fig. 3—Twelve-Pole—8750-kv-a.—6600-Volt—500 rev. per min.—Three-Phase Generator

tests which shall be regarded as satisfactory criteria for determining the temperature rise. Several methods are in vogue, but for testing a single large machine, no method in common use is thoroughly satisfactory. Doubtless the matter will be given very careful consideration by the Standards Committees before rules are adopted.

The author has already mentioned some large waterwheel generators which he recently tested. These were 500-rev. per min., 50-cycle three-phase generators with a ratio of 8750-kv-a. These machines were of the design indicated in Fig. 3. Advantage was taken of the opportunity to employ for the heat test a method which may be termed a cyclic heat run.* It appears to

*This cyclic method of testing electrical machines was first described in an article by Hobart and Punga in the *Electrical World* for April 22, 1905.

See also an article by the author in the *General Electric Review* for November 1911, entitled "A Method for Testing the Heating of Large

Digitized by Google

be especially well adapted to a machine of the kind tested. The test consisted in operating the machine for alternate 15-minute periods on open circuit with super-normal pressure and on short circuit with super-normal current. The degree of the super-normality was so selected as to occasion in each complete half-hour cycle, as nearly as practicable, the conversion into heat of the same amount of energy in each part of the machine as would be occasioned in each part were the machine to deliver the actual load which it was the object of the test to investigate. The normal pressure of the machine was 6600 volts between terminals. (3800 volts per phase) and heat tests were required at each of the three different loads set forth as follows:

Designation of heat run	Kilovolt amperes	Power factor	Current per phase	Terminal pressure
I	7,000	1.00	614 amperes	6600 volts
II	8,750	0.80	766 "	" "
III	10,937	0.80	960 "	" "

For each of the three heat runs it was desired to provide heating conditions equivalent to the loads just set forth. This was accomplished by cyclic tests with the following conditions:

Designation of heat run	I	II	III
For the short circuit periods			
Rotor excitation (amperes)	119	148	185
75-deg. rotor I^2R loss (kw.)	5.10	7.9	12.4
Stator current (amperes)	854	1070	1344
75-deg. stator I^2R loss (kw.)	24.0	37.8	60.0
Stray load loss (kw.)	18.0	25.5	42.3
For the open circuit periods			
Rotor excitation (amperes)	327	327	324
75-deg. rotor I^2R loss (kw.)	38.5	38.5	38.0
Terminal pressure (volts)	8420	8420	8350
Core loss (kw.)	270	270	260

Before these values were determined upon, curves of no-load excitation, short-circuit excitation, core loss and stray load-loss

Alternators." On February 28, 1913 this and other "Methods of Testing Apparatus for Performance" were discussed at the Midwinter Convention of the A. I. E. E. For this discussion see pp. 714 to 721 of Vol. XXXII of TRANS. A. I. E. E.

Digitized by Google

had already been taken. These are reproduced in Figs. 4, 5 and 7. The resistances of the windings had also been measured and reduced to the 75-deg. reference values.† The resistances were:

Stator winding per phase	0.0110 ohm
Rotor winding	0.360 ohm

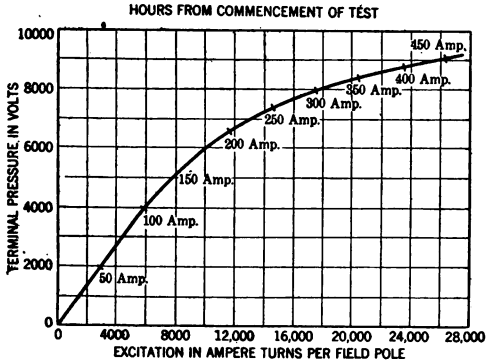


FIG. 4—NO-LOAD SATURATION CURVE OF 12-POLE—8750-KV-A.—6600-VOLT—500-REV. PER MIN.—THREE-PHASE GENERATOR

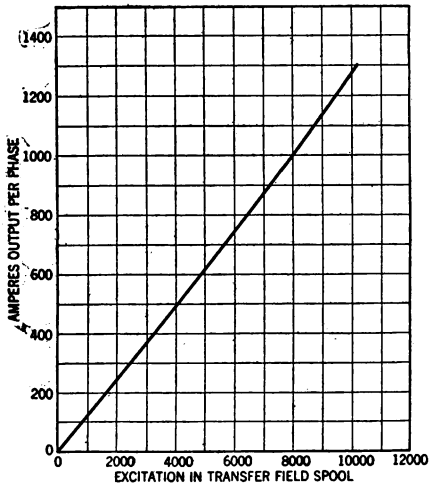


FIG. 5—SHORT-CIRCUIT EXCITATION CURVE OF 12-POLE—8750-KV-A.—6600-VOLT—500-REV. PER MIN.—THREE-PHASE GENERATOR

The value of the internal windage was estimated to be 30.0 kw.

The extent of the equivalence to the actual losses for the three loads is seen from the data in the following table:

†Section 432 of the American rules is to the effect that "the efficiency, at all loads, of all apparatus, shall be corrected to a reference temperature of 75 degrees."

Digitized by Google

		Losses during the:		Average losses during cyclic test	Losses corresponding to actual load of 7000 kv-a. at at P.F. = 1.00
		Open-circuit half of the cycle	Short-circuit half of the cycle		
HEAT RUN I	Stator I^2R	0	24.0	12.0	12.5
	Rotor I^2R	38.5	5.1	21.8	17.8
	Core loss	270.0	0	135.0	119.0
	Stray load loss	0	18.0	9.0	11.5
	Internal windage	30.0	30.0	30.0	30.0
	Total loss =			207.8 kw.	190.8 kw

		Losses during the:		Average losses during cyclic test	Losses corresponding to actual load of 8750 kv-a. at P.F. = 0.80
		Open-circuit half of the cycle	Short-circuit half of the cycle		
HEAT RUN II	Stator I^2R	0	37.8	18.9	19.4
	Rotor I^2R	38.5	7.9	23.2	27.9
	Core loss	270.0	0	135.0	119.5
	Stray load loss	0	25.5	12.8	15.3
	Internal windage	30.0	30.0	30.0	30.0
	Total loss =			219.9 kw.	212.1 kw.

		Losses during the:		Average losses during cyclic test	Losses corresponding to actual load of 10937 kv-a. at P.F. = 0.80
		Open-circuit half of the cycle	Short-circuit half of the cycle		
HEAT RUN III	Stator I^2R	0	60.0	30.0	30.5
	Rotor I^2R	38.0	12.4	25.2	32.6
	Core loss	260.0	0	130.0	120.0
	Stray load loss	0	42.3	21.2	21.5
	Internal windage	30.0	30.0	30.0	30.0
	Total loss =			236.4 kw.	234.6 kw.

The temperatures of the circulating air were determined at the inlet and outlet from the mean of the readings of several ther-

Digitized by Google

mometers. The results and the "Loss per Degree Air Rise," are given as follows:

Designation of heat run	Total loss in machine	Air rise in machine	Loss per degree air rise
I	208 kw.	12.4 deg.	16.8 kw.
II	220 kw.	13.0 "	16.9 kw.
III	236 kw.	15.5 "	15.3 kw.
Average value for loss per degree air rise			16.3 kw.

It can fairly be assumed for this particular design that the heat corresponding to 90 per cent of the loss in the machine is

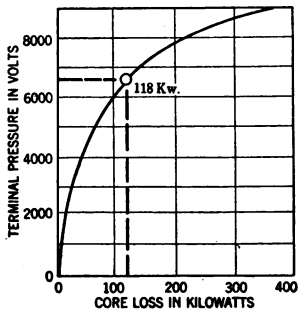


FIG. 6—CURVE OF CORE LOSS OF 12-POLE—8750-KV-A. — 6600-VOLT —500-REV. PER MIN. THREE-PHASE GENERATOR

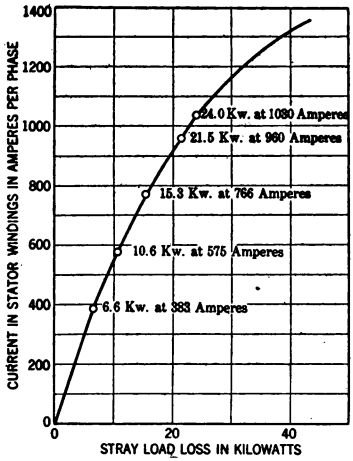


FIG. 7—CURVE OF STRAY LOAD LOSS OF 12-POLE—8750-KV-A.— 6600-VOLT—500-REV. PER MIN.— THREE-PHASE GENERATOR

carried off by the circulating air, the remaining 10 per cent being dissipated from the surfaces of the machine.

Therefore we have, as carried away by the circulating air:

$$16.3 \times 0.90 = 14.7 \text{ kw. per degree rise.}$$

One kilowatt raises the temperature of 1000 cu. ft. (28.3 cu. m.) of air per minute by 1.78 deg., or:

A temperature rise of 1 deg. will be occasioned by a loss of 1 kilowatt for a circulation of 1780 cu. ft. (50.4 cu. m.) per min.

Consequently we have:

Quantity of circulating air $= 14.7 \times 1780 = 26{,}200$ cu. ft. per min. (742 cu. m.).

Digitized by Google

In the following table are brought together for the three heat runs the results obtained by the embedded temperature detectors in the locations designated by A and B in Fig. 1, and also the results for the mean of A and B.

Designation of heat run		I	II	III
Total loss in machine		203 kw.	215 kw.	236 kw.
Temperature rises by embedded detectors	Location–A.	33.0 deg.	36.0 deg.	41.5 deg.
	Location–B.	26.3 "	28.8 "	29.3 "
	Mean of A & B.	29.7 "	32.4 "	35.4 "
Loss per degree of mean rise		6.84 kw.	6.64 kw.	6.70 kw.
Average for the three heat runs for the loss per deg. of mean rise		**6.73** kilowatts		

It is to be noted that by mean rise by embedded detectors is meant the mean of the two maxima, the one being the maximum for location A and the other being the maximum for location B.

The results for these three heat runs by the cyclic method deviate from the average result by less than 2 per cent in the case of the "Loss per Degree Mean Rise by Embedded Detectors" and by only 6 per cent in the case of the "Loss per Degree Air Rise in Machine." These values speak well for the accuracy of the cyclic test.

These and the temperature rises obtained at other parts are brought together in the following summary in which the results from which the highest "hottest spot" temperatures are deduced, are in heavy type.

Designation of heat run		I	II	III
Kilovolt amperes		7000	8750	10937
Power factor		1.00	0.80	0.80
Terminal pressure (volts)		6600	6600	6600
Current (amperes)		614	766	960
Maximum observed rise by temperature detectors		**33.0**	36.0	41.5
Observed by temperature detectors	In location "A"	33.0	36.0	41.5
	" " "B"	26.3	28.8	29.3
	Mean of A & B	29.7	32.4	35.4
Maximum observed rise of rotor winding winding		19.0	19.0	20.5
Observed rise stator winding by resistance		**28.0**	**34.5**	**42.0**
Air rise in machine		12.4	13.0	15.5
Deduced hottest-spot temperature corresponding to ambient temp. of reference		78.0	84.5	92.0

Digitized by Google

It is interesting to note that in heat runs II and III the hottest-spot temperature corresponds to the observations of the rise of

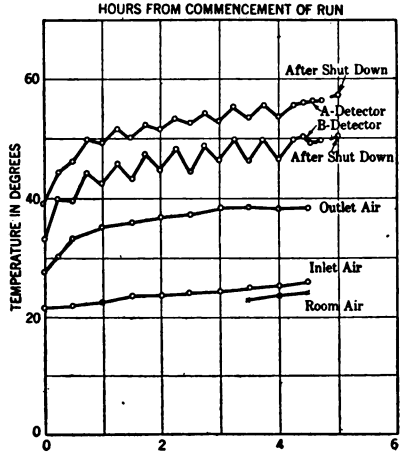


FIG. 8—TEMPERATURE-TIME CURVES FOR CYCLIC HEAT RUN EQUIVALENT TO 7000 KV-A. AT POWER FACTOR = 1.00

the stator winding by resistance and not to the results obtained by the embedded detectors. This is for the reason that the Standardization Rules require 10 deg. to be added to the observed

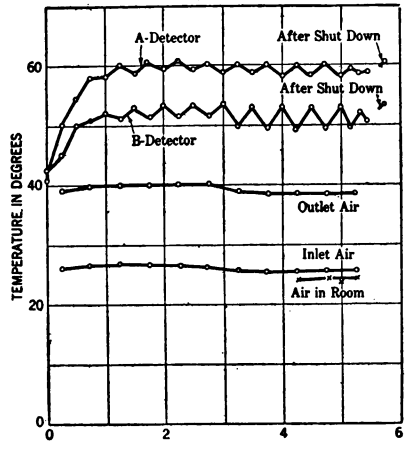


FIG. 9—TEMPERATURE-TIME CURVES FOR CYCLIC HEAT RUN EQUIVALENT TO 8750 KV-A. AT POWER FACTOR = 0.80

temperature as determined by the resistance method and require 5 deg. to be added to the observed temperature as determined from the highest reading of any of the embedded

Digitized by Google

detectors. Such results may occur in machines so designed that no part of the stator winding is much hotter or cooler than the *average* temperature of the stator windings.

In Figs. 8, 9 and 10 are given curves showing the progress of the heating during the cyclic tests.

It should be understood that this paper has been chiefly confined to a discussion of those parts of the temperature sections of the Rules which deal with rotating machinery and that even in this small portion of the rules there are various matters of interest and importance which have not been considered. On

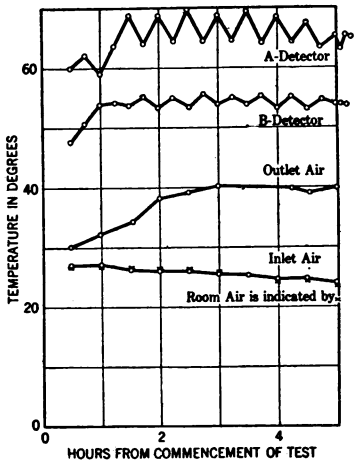


FIG. 10.—TEMPERATURE CURVES FOR CYCLIC HEAT RUN EQUIVALENT TO 10,937 KV-A. AT POWER FACTOR = 0.8

the subject of transformers there are further matters of importance in the temperature sections. The sections on dielectric tests and those on efficiency and regulation present features of at least equal importance as regards both rotating machinery and transformers.

The author entertains the hope that his paper soon may constitute one of several papers by others along these general lines and that by making this beginning he may have promoted in some measure the important undertaking of standardization of electrical machinery.

Digitized by Google

APPENDIX

A Comparison of the Temperature Limits in the British and the American Rules for Electrical Machinery

In the following collection of Tables the three methods of determining the temperature are designated I, II and III, following the arrangement in the American rules. Briefly these methods are defined in the American rules as follows:

Designating number of method	Designating name of method	Description of method
I	Thermometer method	This method consists in the determination of the temperature, by mercury or alcohol thermometers, by resistance thermometers, or by thermo-couples, any of these instruments being applied to the hottest accessible part of the completed machine, as distinguished from the thermo-couples or resistance coils embedded in the machine as described under Method No. III.
II	Resistance method	This method consists in the measurement of the temperature of windings by their increase in resistance, corrected to the instant of shut-down, when necessary. In the application of this method, thermometer measurements shall also be made whenever practicable without disassembling the machine, in order to increase the probability of revealing the highest observable temperature. Whichever measurement yields the higher temperature, that temperature shall be taken as the "highest observable" temperature.
III	Embedded temperature detector method	This method consists in the use of thermo-couples or resistance temperature detectors, located as nearly as possible at the estimated hottest spot. When Method No. III is used, it shall, when required, be checked by Method No. II; the hottest spot shall then be taken to be the highest value by either method, the required correction factors being applied in each case.

Limits of Observable Temperature for Class A and Class B Materials when Method III is Used

When Method III is used, the limits set forth in the British and A. I. E. E. Rules are identical and are set forth below for machines of various voltages.

Digitized by Google

Digitized by Google

Digitized by Google

ted by
ctors il-side ween dge
is B
legrees
"
"
"
"
"
"
"

356 of
stators
width
lts and
is not
s that:
tectors
wound

Digitized by Google

Digitized by Google

Voltage of Machine	Permissible limits of temperature as measured by embedded temperature detectors			
	Temperature detectors located between top and bottom coil-sides in two-layer windings		Temperature detectors located between coil-side and core and between coil-side and wedge	
	Class A	Class B	Class A	Class B
Not over 5000 volts.....	100 degrees	120 degrees	95 degrees	115 degrees
Between 5000 & 6000 volts ..	100 "	120 "	94 "	114 "
" 6000 & 7000 "	100 "	120 "	93 "	113 "
" 7000 & 8000 "	100 "	120 "	92 "	112 "
" 8000 & 9000 "	100 "	120 "	91 "	111 "
" 9000 & 10000 "	100 "	120 "	90 "	110 "
" 10000 & 11000 "	100 "	120 "	89 "	109 "
" 11000 & 12000 "	100 "	120 "	88 "	108 "

NOTE: Method III, (Defined and discussed in sections 352 to 356 of the A. I. E. E. Rules) is, in the A. I. E. E. Rules mandatory for all stators of machines (exclusive of induction regulators) with cores having a width of 50 cm. (20 inches) and over, and also for all machines of 5000 volts and over, if of over 500 kv-a., regardless of core width. The method is not mandatory in the British Rules but section 63 of those rules states that: "When so specified with the inquiry, embedded temperature detectors shall be employed in the case of a machine of over 3000 kilowatts if wound for a rated pressure exceeding 3300 volts."

Digitized by Google

Digitized by Google

To be presented at the 330th meeting of the American Institute of Electrical Engineers, Chicago, Ill., March 9, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

RELAYS FOR HIGH-TENSION LINES

BY PHILIP TORCHIO

ABSTRACT OF PAPER

The author considers the following arrangements desirable:

For *radial feeders not in parallel*—inverse-time-limit overload relays, with selective ground relays. *Radial feeders in parallel*—reverse-power relays in combination with reverse-time-element relays, or the balanced system. *Single lines in tandem*—definite and inverse-time-limit relays with progressively longer time settings near the generating station. *Two or more parallel lines in tandem*—inverse-time-limit relays at the points where the power leaves the station or substation, and overload relays in combination with reverse-power relays at the points where the power enters the substation; also, the balanced system preferable, when possible. *Single line ring systems*—inverse-time-limit relays, combined with reverse-energy relays, or, preferably, the balanced system. *Parallel line ring systems*—inverse-time-limit relays on the outgoing feeders at the generating stations, and a balanced interconnected combination of reverse-energy and inverse-time-limit relays at the receiving ends of the supply feeders. *Tie lines*—some balanced arrangement. *Generator relays* seldom used, but arrangements are suggested. *Transformers*—differential relays. Special grounding relays for *extra high-tension cable feeders.*

Appendices A, B, C describe connections of reverse-power relays, relay testing and a special installation.

I. INTRODUCTION

DURING the past two or three years important papers and discussions have been published describing the latest developments and operating results regarding relays for high-tension lines.

These developments have narrowed down to certain specific arrangements based on different fundamental principles and each requiring characteristically different types of relays. I shall not here describe the structural and operating details of all these types of relays. Full descriptions can be found in the references and other literature. I shall, however, attempt to review the most prominent systems of relay protection and their fields of application, pointing out for a few practical cases the combinations used to obtain the maximum degree of protection

Manuscript of this paper was received February 8, 1917.

Digitized by Google

with minimum expenditure, especially for the conditions of existing lines.

II. Definitions

Certain terms and expressions have assumed, in practise, specific meanings. Those used in this paper are defined as follows:

Radial feeders or independent feeders. Lines transmitting power from a generating station (or main source of supply) to a substation or a customer's installation.

Radial feeders are operated (or not operated) *in parallel* at the substations according to whether their high-tension terminals are *metallically* connected to the same high-tension bus bars or to independent high-tension bus bars (which may feed, through transformers, the same set of low-tension bus bars).

Lines in tandem—feeders from a generating station supplying two or more substations in series.

Lines connected in ring, or *closed feeder circuits*—two or more substations connected in series with the two outside substations, each connected by separate feeder or feeders to the generating station.

Tie lines—connections between generating stations or between substations not in the order of the ring. The latter are often called *connectors*.

III. Relay Protection

The object of relay protection is to disconnect any part or section of the system on which a fault occurs, but leave the rest of the system in operation without being further affected by the faulty section.

It is to be noted that the function of the relay is not any longer correlated to the idea of protection of apparatus against overloads. The relay is intended to operate only on breakdowns and not on overloads, though its setting is usually given in per cent overload of the rated capacity of the circuit.

IV. Radial Feeders not in Parallel

For radial feeders not operated in parallel at the substation, overload relays of the inverse-time-limit type have generally and successfully been used in this country. Fig. 1 shows a one-line diagram together with the relay connections and relay characteristics that one of the large operating companies has used successfully.

In addition, for over ten years several large companies have operated a system of selective-ground relays to indicate a ground on the affected feeder. * The long reliable experience which this system has given seems to warrant further applications in

*Trans. A. I. E. E., 1903, Vol. xxi, p. 417.

Digitized by Google

this country; extensive use has already been made abroad in the past five or six years. † These relays should be particularly valuable for high-tension service customers in conjunction with overload relays.

Generally speaking, radial feeders not operated in parallel at the substation can be protected with overload and selective-ground relays and, on large systems, protective feeder reactors to obtain 100 per cent protection to the system.

V. Radial Feeders in Parallel

Radial feeders operated in parallel at the substations present greater difficulty for their relay protection. The best practise utilizes two different methods, namely: (a) the reverse-power

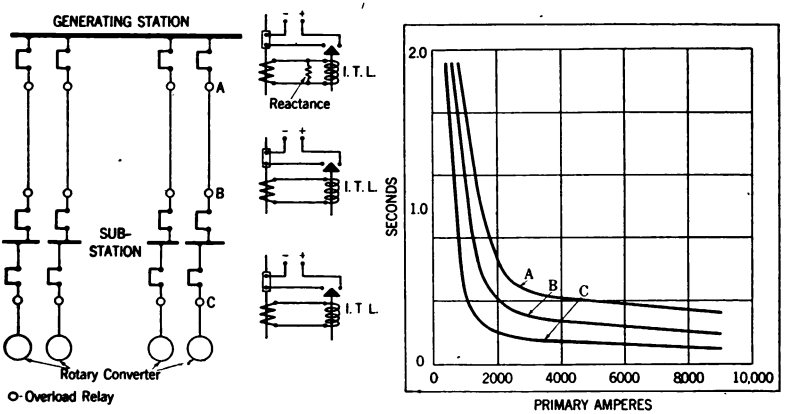


FIG 1
Radial feeders not paralleled—one-line diagram

relay in combination with overload relays and (b) the balanced or Merz-Price system. The balanced system is one where the current, when flowing in the same direction and of the same relative magnitude, in parallel conductors or in different portions along the length of the same conductor, will not produce any force on the relay even under heavy short-circuit conditions. The relays are only operated when the currents are of different relative magnitude or direction at these points.

(a) *Reverse-power relays* have, in isolated cases, given very satisfactory results. The recent developments in the induction-type reverse-energy relays have made it possible to use this form of protection more exten-

†The Journal of the Institution of Electrical Engineers (London) p. 159, Jan. 15, 1915.

Digitized by Google

sively as these relays are made so that they will properly select down to ½ per cent voltage.

In cases where a number of feeders are paralleled in the substation, a combination of balanced and reverse-energy relay connections, as shown in Fig. 2 gives very satisfactory results.*

Appendix C outlines the plans of the New York Edison Company for two of its principal substations where this combination is used in connection with selective-ground relays.

(b) The *balanced system* of which the *split conductor system* is an illustration, has given such satisfactory results abroad that it has lately been introduced in this country by several large companies, like the Boston Edison Company and the Public Service Electric Company of New Jersey. It is especially suitable for new installations or where existing duplicate overhead lines can be coordinated to give a resultant split-conductor circuit.†

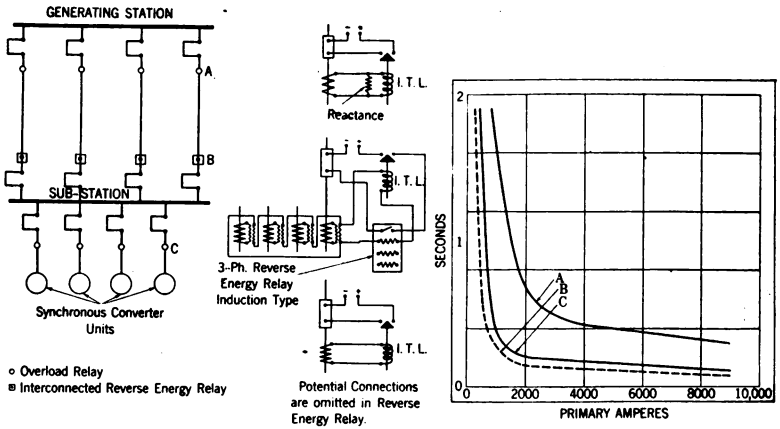


FIG. 2

Parallel feeders—one-line diagram

VI. LINES IN TANDEM

For single lines in tandem, extensive use has been made of definite and inverse-time-limit relays, with progressively longer time settings on relays near the generating station.

For two or more parallel lines in tandem, the inverse-time-limit relays at the points where the power leaves the station or substation, and overload relays in combination with reverse-power relays at the point where the power enters the substation, have given very satisfactory results. In Fig. 3 a one-line diagram is shown of a system that has been in operation for some time with excellent results.

*Journal of the Institution of Electrical Engineers (London) p. 159, Jan. 15, 1915.

†PROCEEDINGS of A. I. E. E., p. 1399, Sept. 1916.

Digitized by Google

In laying out a system of parallel feeders in tandem, it has been found very advantageous to make a careful analysis of the constants of the circuits and short-circuit conditions, to set the relays to give the best selective action. As an example, the equivalent 7800-volt constants of each circuit shown in Fig. 3 are:

Generating station to substation No. I—Reactance **1.45 ohms, resistance 0.53** ohms per leg.

Substation No. I *to No.* II—Reactance 0.33 ohms, resistance **0.31 ohms** per leg.

Substation No. II *to No.* III—Reactance 4.3 ohms, resistance **3.7 ohms** per leg.

The settings of the various relays are given in the curves of Fig. 3 and from the maximum short-circuit currents that can

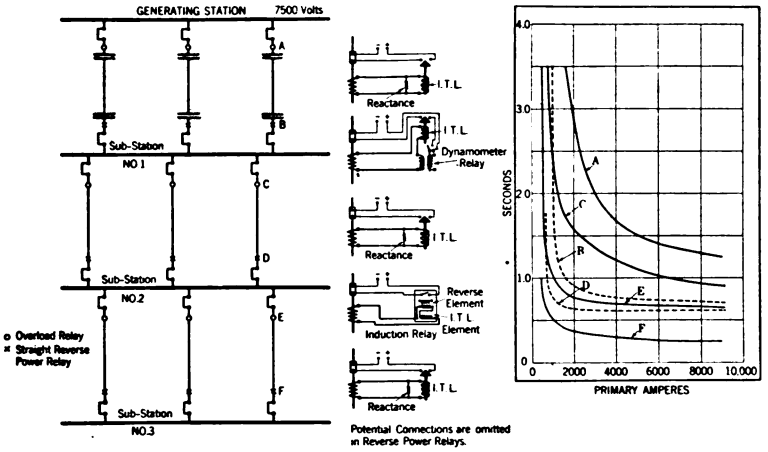


FIG 3
Parallel feeders in tandem—one-line diagram

pass through any two relays in series, there is a selective time difference of half a second, even under the most severe conditions.

The balanced system, as explained in Section 5, is also especially adapted for parallel lines in tandem.

VII. SINGLE LINE RING SYSTEMS

On single line ring systems, inverse-time-limit relays combined with reverse-energy relays may be used with the settings on the inverse-time-limit element made progressively longer near the generating station when feeding in the outgoing direction. The balanced system might be preferable to the above especially in cases of new installations.

Digitized by Google

VIII. Parallel Line Ring System

In a parallel line ring system, the system of relays shown in the one-line diagram Fig. 4 gives promise of very good results.

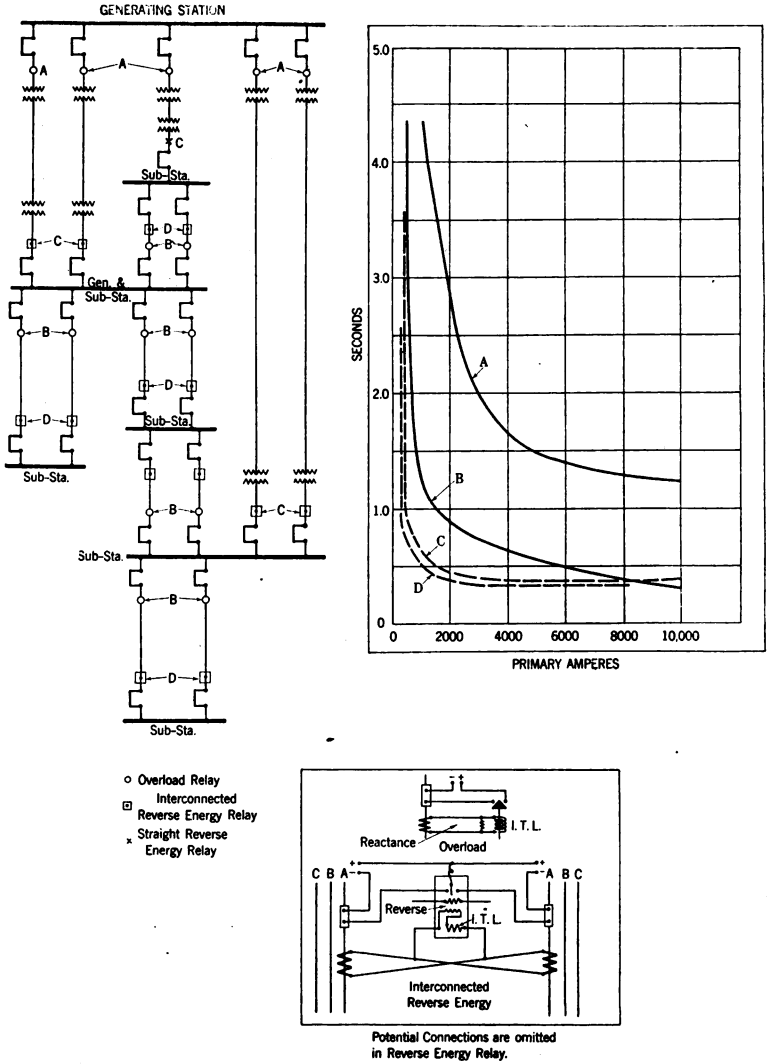


FIG. 4

Parallel feeders—ring network—one-line diagram

In this the inverse-time-limit relays are used on the outgoing feeders at the generating stations and a balanced interconnected combination of reverse-energy and inverse-time-limit relays at the receiving ends of the supply feeders.

Digitized by Google

In the case shown, the supply is furnished to several parts of the system, which parts are interconnected through several substations by duplicate feeders. Here the overload relays are used on the outgoing feeders at each of the main receiving substations to eliminate the possibility of a complete system shut-down due to the failure of any relay to function properly or in case of a short circuit on a bus.

IX. Tie Lines

With tie lines between generating stations where power can pass in either direction, the Merz-Price or balanced system of relays are probably most advantageous. The balanced arrangement may be on the split-conductor principle, the combination interconnected reverse-power and inverse-time-limit relay as shown in Fig. 2 or a mechanical interlock between the plungers of the several relays on the parallel feeders.

X. Generator Protection

Generators are seldom protected by relays; however, protection in cases of short circuits in generator windings may be best obtained by means of differential relays connected to current transformers in the two ends of each individual winding. It is also possible to protect against this trouble by means of reverse-power relays in connection with overload relays with their tripping contacts in series and set to trip out the switch at a high value of current, when the power is flowing in the direction of the generator.

As in most cases the generator breakdowns start with a ground, a good protective arrangement consists in adopting the selective relay ground principle, as in the case of feeder protection. For this arrangement precaution must be taken to ground the system either by a ground placed outside of the generator neutral, or by grounding the neutral of one or more generators and passing these grounding leads through the transformer of the selective ground relay system.

XI. Transformer Protection

Transformer protection has been best obtained for a very long time by means of differential relays connected to transformers on both the high-tension and low-tension sides of the power transformer.

Digitized by Google

XII. Grounding Relays

Special grounding relays have been found very important for use on extra high-tension feeders. The accompanying Figs. 5 and 6 show the method that has been used by The New York Edison Company where the high-voltage feeders are metallically isolated at both ends with transformers.

While the experience is not conclusive, it is interesting to note

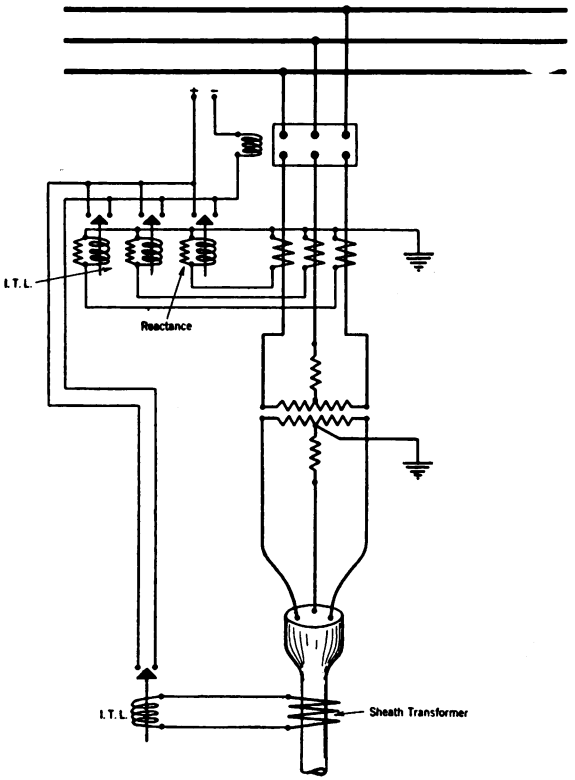


Fig. 5

that in the case of Fig. 5, on 15 miles (24.1 km.) of 25,000-volt cable, eleven cable breakdowns occurred in the first seven months of service without the grounding relays, whereas only five cable breakdowns have occurred in the past year with the grounding relays. Of the first eleven breakdowns, six occurred in service and five under test after a service breakdown. Of the latter five breakdowns all occurred in service and none under test. The theory is held that the grounding relay clears the

Digitized by Google

trouble before the short circuit through the impaired insulation has sufficient time to develop a large flow of current creating heavy surges and mechanical stresses which may weaken other points on the system.

APPENDIX A

The reverse-power relay cannot be considered to give any selective time feature as the moving torque is dependent upon

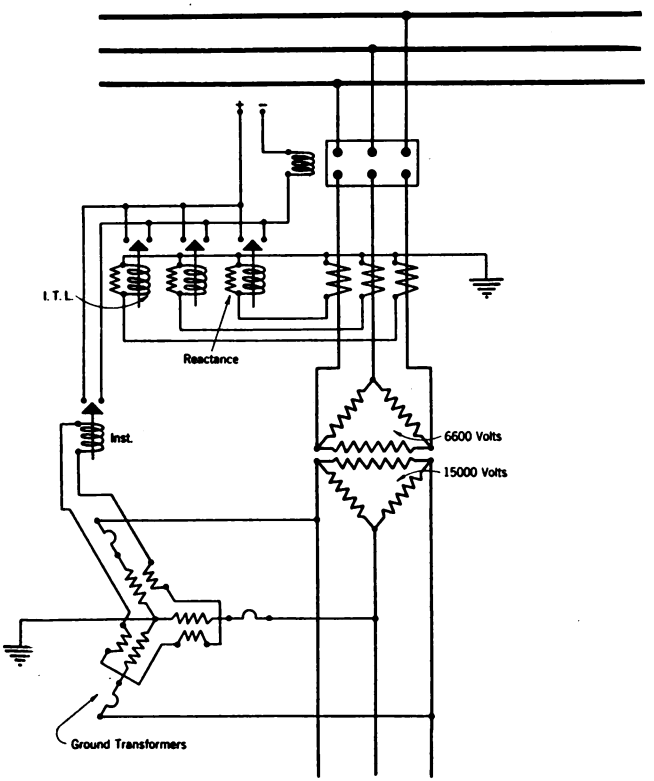


FIG. 6

the power factor and the voltage of short-circuit conditions. In order to obtain the best results, the reverse-power relay should be set as sensitive as possible, with an inverse-time-limit relay for time and current adjustments. The tripping contacts of the two relays should be in series so that the circuit will only trip out with a short-circuit current flowing in a given direction and of a certain magnitude. The time required to trip is then dependent upon the magnitude of the current alone.

Digitized by Google

The power factor of a short circuit may vary from practically zero to unity, and in addition there is a second possible shifting of phase relation from Y voltage of 90 electrical degrees, due to voltage distortion on single-phase short circuits. This necessitates the reverse-power relay selecting through a range of 180 degrees.

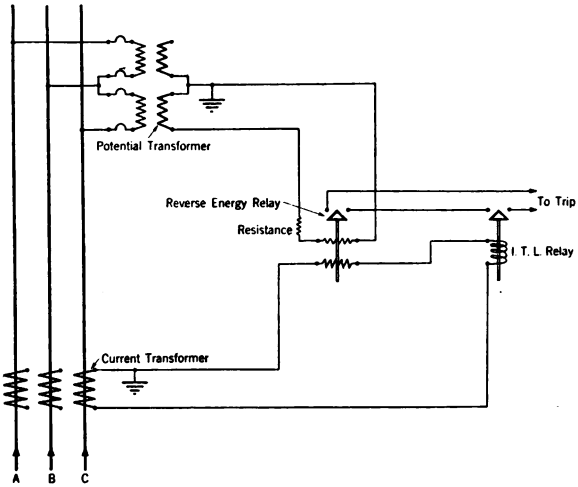


FIG. 7—PHASE ROTATION A B C

It is therefore very important that the relays have their potential and current coils properly connected to select under all of these conditions. Fig. 7 shows the method of connection that The New York Edison Company has employed for the last four years with very satisfactory results. Fig. 8 shows another

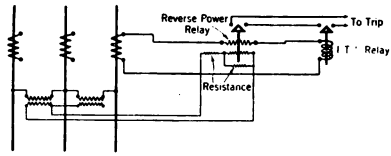


FIG. 8—REVERSE-POWER RELAY CONNECTIONS

method of connection that is proposed by one of the manufacturing companies and gives promise of good results.

In both of the above connections the current in the current coil leads the current in the potential coil with unity power factor three-phase reverse power. Hence the currents in the two coils are in closer phase relations with the lagging current of

Digitized by Google

short circuits. Also the potential elements are connected in delta which limits the distortion on single-phase short circuits to 30 electrical degrees in place of 60, as in the case of a Y connection.

APPENDIX B

Relay Testing To insure selective operation when carrying short-circuit currents, the relays should be tested under conditions approximating, as nearly as possible, short-circuit conditions. This involves heavy testing currents, and correspondingly short timing intervals, both of which present certain difficulties.

In keeping with the foregoing considerations, marked changes

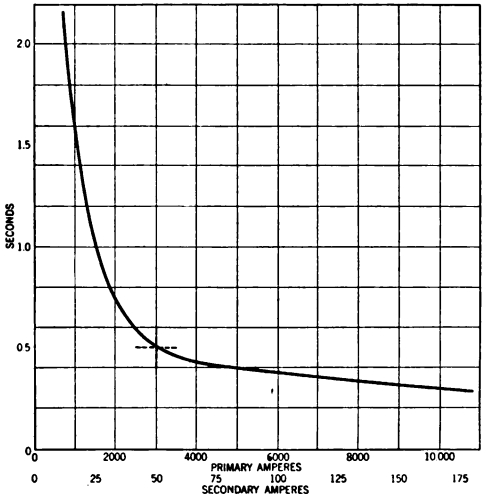


FIG. 9

have taken place in the testing of series inverse-time-limit relays in the generating stations of The New York Edison Company. A brief outline of the present method employed is given, together with sketches of the testing circuits, etc.

Although the general scheme remains the same as heretofore, the testing is now done at considerably higher currents and an accurate automatic timer has replaced the stop watch and signal lamp. Furthermore additional testing circuits have been provided, and the test connections are made to give a more complete check on the condition of the relay circuits.

The extent to which the testing currents could be increased was necessarily limited by the size of wire on the relay circuits.

Digitized by Google

These circuits are all of No. 10 A. W. G. copper wire and a testing current approximating 50 amperes was considered to be a safe maximum. A circuit breaker which is automatically opened when the relay closes is used in the testing circuit to prevent injury to the wiring by leaving the test current on for too long a period.

A secondary test current of 50 amperes corresponds to about 10 times the normal capacity of the circuits and is well down near the flat part of the inverse-time-limit relay curves (see Fig.

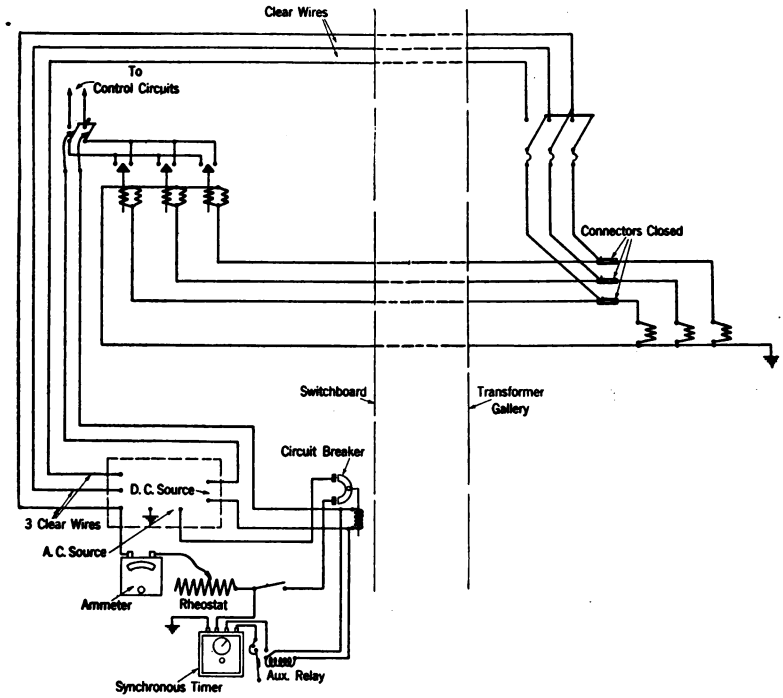


FIG. 10

9.). It will be noted that at this part of the curve an error in current measurement will have a considerably smaller effect on the timing than at a point of the curve corresponding to two or three times the normal circuit capacity.

The curve, Fig. 9, also shows that the time at 50 amperes secondary is about 0.5 second. It is, of course, impossible to measure this interval with sufficient accuracy by use of a stop watch, and a small synchronous timer is used. This instrument is accurate to 3 or 4 per cent at 0.5 second and good results have

Digitized by Google

been obtained with it. The operation is entirely automatic, eliminating all personal errors as shown in the method of connections in Fig. 10.

The connectors on the current-transformer test blocks are not removed under tests, which leaves the secondary of the current transformer in shunt with the relay circuit while testing. Under these conditions and with test currents not exceeding 50 amperes, only a very negligible current is shunted out by the transformer secondary. If, however, a high resistance is present in the relay circuit or if the impedance of the transformer is low on account of short-circuited turns, the balance of current between the relay and transformer will be disturbed and the defective circuit will be found on periodic retest of the relay. This method has already proven very successful in locating defective current transformers.

If it were possible to test with still higher currents, then, with the transformer shunting the relay circuit, an appreciable part of the test current will pass through the transformer secondary. This would be a big advantage as it would account for the high magnetizing current which changes the ratio of the transformer when working under short-circuit conditions.

APPENDIX C

The New York Edison is installing the protective relay system for the generating station and some of its substations where all the radial feeders are operated in parallel, as shown in Fig. 11.

This company has used the system of selective-ground relays for nine years with excellent results. This system was arranged to ring a bell and locate a defective grounded feeder by means of a relay drop which was in turn connected to a current transformer that enveloped the three conductors.

By this indication the operator was in former years able to disconnect the defective cable before it developed into a short circuit in about 80 per cent of the cases.

With the increase in size of the underground system the grounding current capacity has increased so much that it gives the operator very little time to disconnect a grounded feeder before it develops into a short circuit. It was, therefore, decided to make this operation automatic and a zigzag three-phase grounding transformer is being connected to the generating station bus for establishing a more positive ground current.

Digitized by Google

The resistance is connected in series with these transformers to limit the current to 200 amperes.

A plunger-type bellows relay is being connected to the ground-sheath current transformer and this relay is being connected to

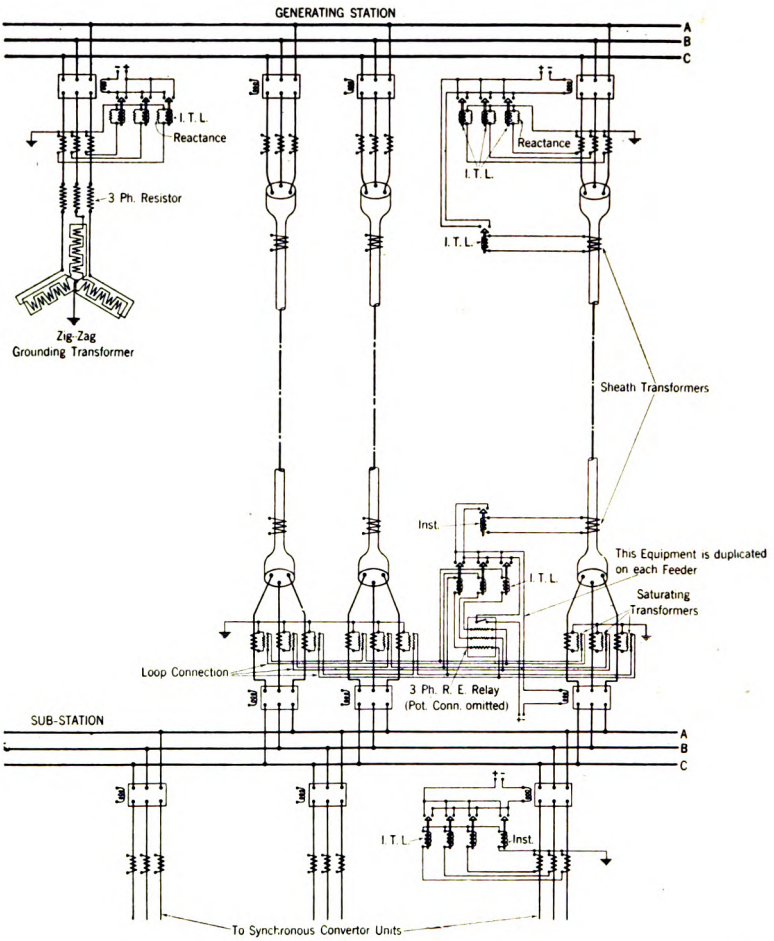


FIG. 11

automatically trip out the oil switch at the station when a ground occurs on the feeder.

In cases where the feeders are paralleled in the substation a grounding relay is used in conjunction with the balanced interconnected reverse-energy relay arrangement of Fig. 2 on the sub-station ends of the feeders. On these feeders the bellows

Digitized by Google

grounding relays in the generating station are given a short time setting to permit the substation switches to operate first.

All feeders outgoing from the substation bus are also equipped with grounding relays.

REFERENCES

L. N. Crichton, The Use of Relays on Alternating-Current Systems. *Electric Journal*, p. 339, July 1916.

E. B. Wedmore, Automatic Protective Switch-gear for Alternating-Current Systems. The Journal of the Institution of Electrical Engineers (London) p. 158, Jan. 15, 1915.

P. H. Chase, Discussion of "Split Conductor" Method of Relay Protection, PROC. A. I. E. E., p. 1399, Sept. 1916.

F. E. Ricketts, The Protection of Transmission Circuits by Relays. *Electric Journal*, p. 227, April 1914.

Paul MacGahan, The Selective Time Element of Relays. *Electric Journal*, p. 91, March 1915.

Paul MacGahan and B. H. Smith, Reverse-Power Relays. *Electric Journal*, p. 417, September 1915.

P. Torchio, Safety Devices in Central Stations and Substations. TRANS. A. I. E. E., Vol. XXI, p. 417, April, 1903.

P. Torchio, Torchio-Varley Method of Protection. TRANS. A. I. E. E., Vol. XXVI, p. 1615, October 1907.

H. W. Clothier, Switchgear and the Isolation of Faults on Power-Supply Systems. The Journal of the Institution of Electrical Engineers (London).

W. C. Yates, Operating Notes on Relays, Contactors, and other Basic Automatic Devices. *General Electric Review*, Vol. XV, p. 279.

F. E. Ricketts, The Restoration of Service after a Necessary Interruption. PROC. A. I. E. E., p. 931, June 1916.

D. Basch, Switchboard Relays and their Application. *General Electric Review*, Vol. XVI, p. 242.

A. R. Haines, An Installation of Reverse-Energy Relays. *Electrical World*, Vol. 65, p. 22, Jan. 23, 1915.

C. C. Garrard, Overload Protection on Alternating-Current Circuits by Tripping Devices. *London Electrician*, Jan. 29, 1915.

Digitized by Google

Digitized by Google

To be presented at the 330th meeting of the American Institute of Electrical Engineers, Chicago, Ill., March 9, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

THE PROTECTIVE RELAY EQUIPMENT ON THE SYSTEM OF THE COMMONWEALTH EDISON COMPANY

BY R. F. SCHUCHARDT

ABSTRACT OF PAPER

Where the use of protective devices is based primarily on the desire to maintain a high continuity of service rather than to protect apparatus, the tendency in the development of large systems is toward interconnection, and to make this practicable, satisfactory relays are necessary.

The paper describes briefly the system of the Commonwealth Edison Company of Chicago with special reference to the protective devices installed thereon.

Generators are equipped with balanced relays, lines with induction-type inverse-time-element relays, some of them of the uni-directional type, and balanced relays, while substation apparatus has the usual equipment of overload relays, speed-limit devices, etc., and outgoing feeders the instantaneous type of relays. The arrangement of these relays is shown and some of the settings described.

INTRODUCTORY

PROTECTIVE relays on a central station system may be defined as devices or apparatus used primarily to maintain continuity in the supply. The protection is with reference to the service rather than to the generator, line, or transformer, etc., to which the relay is connected. The ideal protective relay is one that immediately disconnects a faulty member of the system before the disturbance caused by the fault has spread beyond that member. Unfortunately, development to date has not yet evolved such an ideal device. Synchronous apparatus has a tendency to drop out of step promptly whenever an unusually heavy shock occurs on the system, thus at times causing disturbance in other than the faulty member. However, the relays now available will serve properly in the great majority of cases and we may hope ultimately to have synchronous apparatus designed with a higher degree of stability.

At the present time the conditions met with in different systems vary considerably, and no one scheme of protection will

Manuscript of this paper was received February 13, 1917.

Digitized by Google

fit them all. Each system must be studied and the individual solution applied. There are, however, many points of similarity and the solution in one case will serve as a partial guide, at least, in others.

The tendency in the development of large systems is toward the simplicity of the low-tension Edison network, which is giving such excellent results. Unfortunately, the protective problem on these large high-tension systems has not the simplicity of the Edison network. We seem, however, to be in a fair way of making satisfactory progress toward this goal. The devices now obtainable and commercially within reach make it practicable to interconnect quite freely and thereby to gain considerably in the use of the copper invested in lines and, in general, to localize faults.

It is only fair to the manufacturer to state that his problem has not been an easy one, since the ideal action of protective relays would require them to have almost human intelligence. They must invariably discriminate between conditions under which they ought to operate and those under which they must remain inoperative, and this discrimination must be made instantaneously. The present apparatus made by the manufacturers reflects credit on their engineers and gives promise of continued progress along the desired lines.

In the following paper will be found a description of the protective schemes recently adopted by the Commonwealth Edison Company of Chicago as a result of considerable experimentation with the newer relays. With the continued growth of the system the earlier relays were frequently found inadequate and it was necessary to seek relief in a better development in order to continue the maintenance of a satisfactory service.

Brief Description of the Plant

The plant of the Commonwealth Edison Company contains at present three main high-tension generating stations with a number of auxiliary peak stations, having a total generating capacity at this time (March 1917) of approximately 400,000 kw., with 800 miles (1287.4 km.) of high-tension transmission lines feeding sixty-six distribution substations and about forty industrial customers' substations. The energy is generated at two frequencies, 25 cycles and 60 cycles. The bus connections of the units and the direct ties between stations are shown in Fig. 1. Summarized substation data are shown in Table I.

Digitized by Google

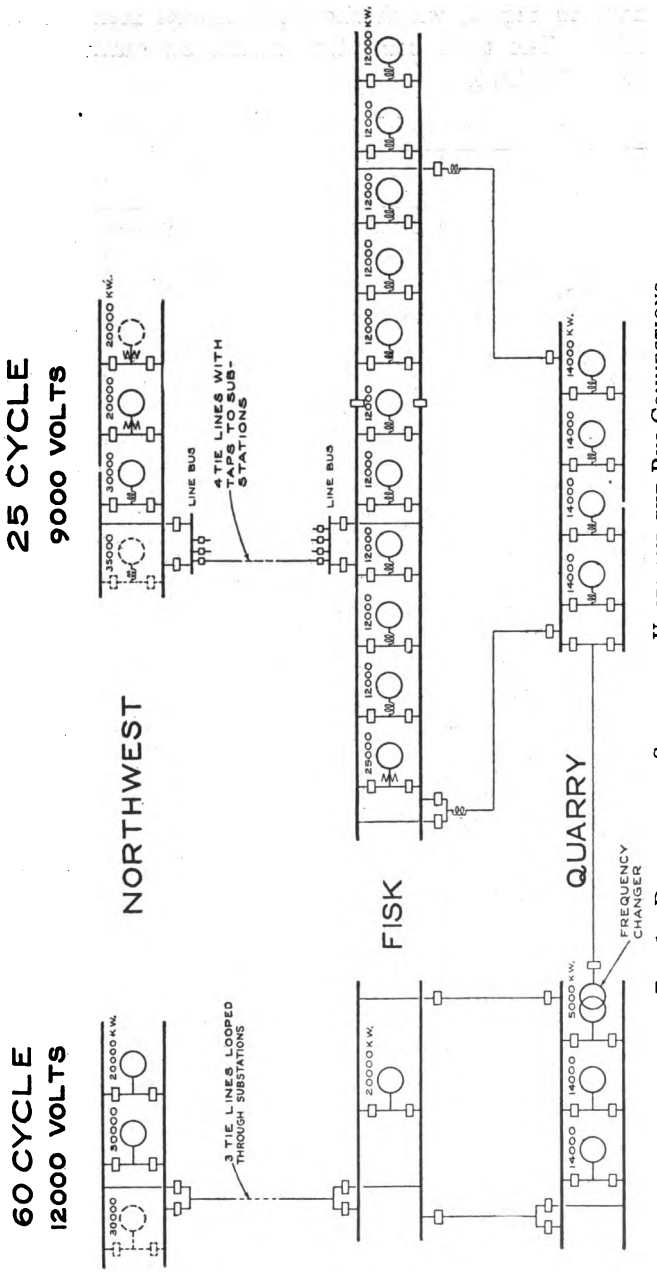


FIG. 1—DIAGRAMATIC SKETCH OF UNITS AND THE BUS CONNECTIONS

Digitized by Google

The size of the system and its growth are indicated in the curves in Fig. 2, which show the annual maximum loads since 1900. The total coincident maximum during the past winter was 370,000 kw.

TABLE I—SUMMARY OF SUBSTATION CAPACITY DATA

	25 Cycle		60 Cycle	
	Total kw. capacity	Range of sizes	Total kw. capacity	Range of sizes
250-volt synchronous converters on Edison system	101,300	100–4200		
600-volt synchronous converters for railway service	*226,000	1000–4000	9,000	3000
12,000-volt to 4,000-volt transformers			102,500	100–3000
Frequency changers	21,500	500-2000		
Total	348,800		111,500	

* 140,000 kw. of this is in substations of the traction companies.

Fig. 3 is a diagram of the transmission lines. The length of these lines at the various voltages is as follows:

481 miles (774 km.) of 9000-volt, 25 cycles; cable size 4/0, 250,000 cir. mils and 300,000 cir. mils.

215 miles (345.9 km.) of 12,000-volt, 60 cycles; same cable as for 9000 volts.

92 miles (148 km.) of 19,000-volt, 25 cycles; cable size 2/0 and 250,000 cir. mils.

12 miles (19.3 km.) of 22,000-volt, 60 cycles; cable size 250,000 cir. mils.

Elements of the System and their Protection

All of the 25-cycle generators in these three stations are provided with external reactors except in the case of two of the units which generate at half pressure and step up to 9000 volts through auto-transformers. The total reactance of generators and external coils (or auto-transformers) is as follows:

12,000-kw.	capacity	generators	.....	8	per cent
14,000 "	"	"	.....	8	" "
20,000 "	"	"	.....	10	" "
25,000 "	"	"	.....	11	" "
30,000 "	"	"	.....	12	" "
35,000 "	"	"	.....	12.5	" "

Digitized by Google

The 60-cycle generators have sufficient inherent reactance, so no external reactors are required, this reactance being,

14,000-kw.	(18,670-kv-a.)	capacity generators...	7	per cent
20,000 "	(25,000 ")	" " ..	12	" "
30,000 "	(35,300 ")	" " ..	12.5	" "

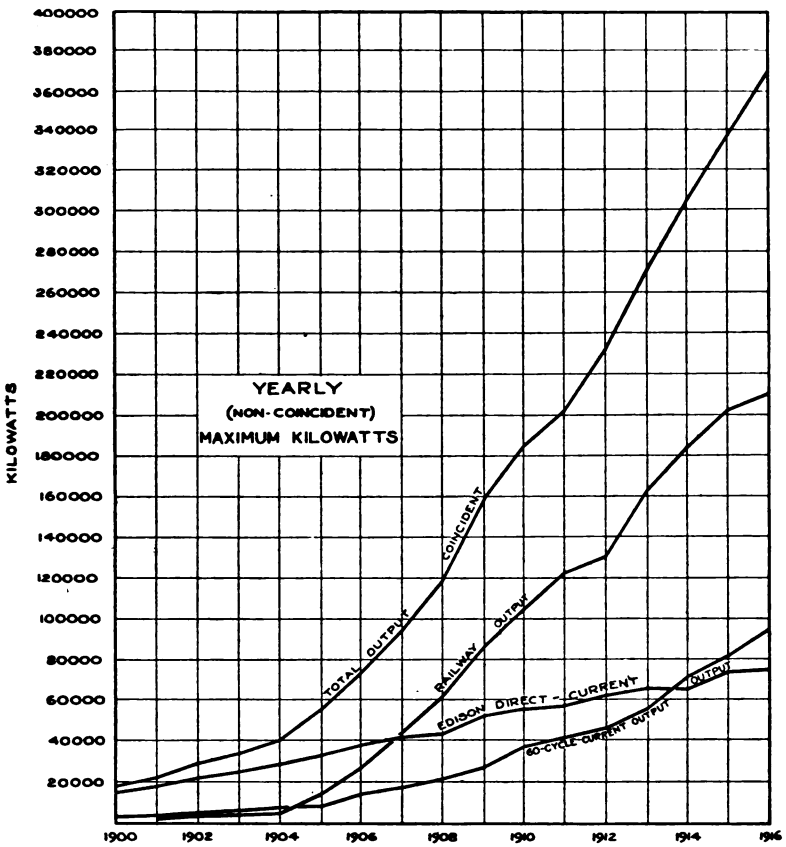


FIG. 2—MAXIMUM LOADS SINCE 1900

With one exception the vertical generators, which include all those under 20,000-kw. capacity and two of this capacity, have no automatic relays at present. All of the newer units and one of the 20,000-kw. vertical units are equipped with balanced relays of the Merz-Price type. These are connected so that in the event of a fault in the generator or in its leads, they will promptly open the main oil switch, the neutral switch

Digitized by Google

(if closed), and the field switch of the faulty unit. A diagram of this relay connection is shown in Fig. 4.

Fisk Street station is normally operated in two sections which, however, are tied together through the Quarry Street bus, sectionalizing reactors being placed in each tie line. (See Fig. 1.) These reactors are designed to absorb 20 per cent of the pressure at the full-load current of the tie line, which consists of three 250,000-cir. mils cables in parallel. These tie lines are protected with balanced relays, the connections of which are shown in Fig. 5. It will be noted that the connections are such that the relays will operate only in the event of ground current, but experience has indicated that the vast majority of cable failures are to ground. Incidentally this could always be assured if cable of the Hochstaedter type—that is, with grounded sheaths around each conductor of the three-conductor cable—

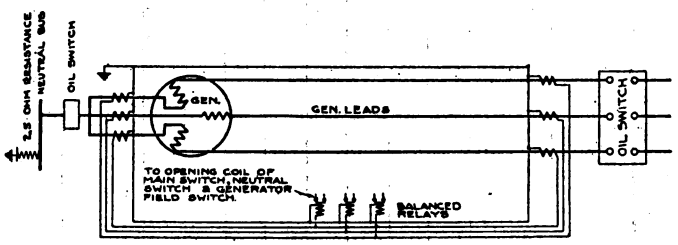


FIG. 4—MERZ-PRICE RELAY ON GENERATOR

were used. Tie lines between Fisk Street and Northwest station which are about eight miles (12.8 km.) long are treated like ordinary lines at each station.

At the Quarry Street station there is a 5000-kw. frequency changer serving as tie between the 25-cycle, 9000-volt busses and the 60-cycle, 12,000-volt busses. The bellows overload relays now on the units are to be replaced by uni-directional relays at either end, and in addition, an adjustable definite-minimum, inverse-time-element relay will be installed to trip the 60-cycle switch in the event of a sustained excessive overload such as would result when either of the systems receives a shock and excessive synchronizing energy passes between them through this frequency changer. The uni-directional relays will be set to operate instantaneously on energy feeding inward and equal to about 15,000 kv-a., while the inverse-time relay will be set for approximately 10,000 kw., three seconds.

Digitized by Google

Digitized by Google

On the transm
lows-type relays
adjustable defini
the line is part o
station end is mo

FIG. 5—DIAGRAMA

relay of the same
Its current settin
which could flow
next link of the
in parallel, whe
tionalizing at th

Digitized by Google

On the transmission lines in the generating stations the bellows-type relays are being rapidly replaced by an induction-type, adjustable definite-minimum, inverse-time-element relay. Where the line is part of a ring and the time setting of the relay at the station end is more than one and one-half seconds, an additional

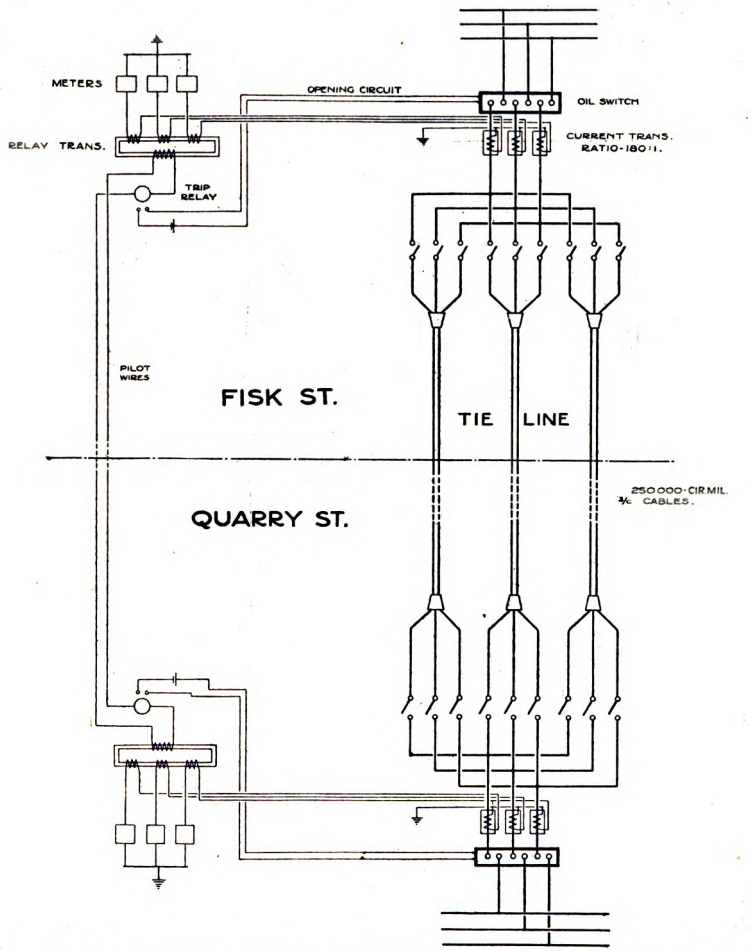


FIG. 5—DIAGRAMATIC SKETCH OF RELAYS ON FISK-QUARRY TIE LINES

relay of the same type is used but set to operate instantaneously. Its current setting, however, is slightly higher than that current which could flow over the resistance of this line and into the next link of the ring. It is planned ultimately to operate lines in parallel, wherever practicable and consistent with the sectionalizing at the generating stations.

Digitized by Google

At the substation end of these lines as well as on tie lines between substations there are connected uni-directional inverse-time-element relays of the induction type, or in some instances on rings, balanced relays, depending on the relation of the particular line to the other elements of the ring of which it is a part.

Protective apparatus in use on substation units is as follows:

On 250-Volt Synchronous Converters of the Edison System. Inverse-time-element overload relays of the bellows type on the high-tension supply to the transformers and operative on the oil switches; speed-limit

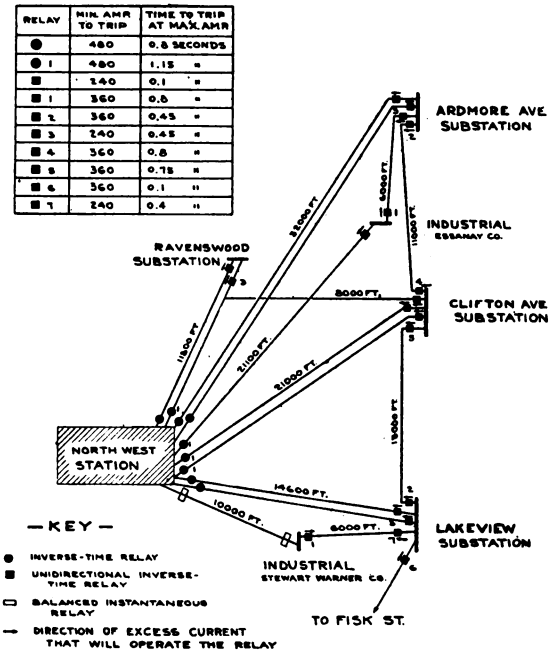


FIG. 6 A—TYPICAL PROTECTIVE SCHEME—TRANSMISSION LINES

devices operating on the d-c. circuit breakers; and on all down-town substation units in addition reverse-current relays operating on the d-c. circuit breakers.

On 600-Volt Converter Units for Railway Service. Inverse-time-element overload relays operating on the oil switch; overload attachment on the positive circuit breaker; speed-limit relays operating on the positive circuit breaker; and in addition a special leakage-current relay connected between the frame of the machine and earth and set to operate both the oil switch and the d-c. breaker in the event of potential in excess of 100 volts existing on the frame, such as might result from a flash-over.

On 60-Cycle, 12,000-Volt to 4000-Volt Transformers. Bellows overload relays operating on the 12,000-volt switch are being replaced by dif-

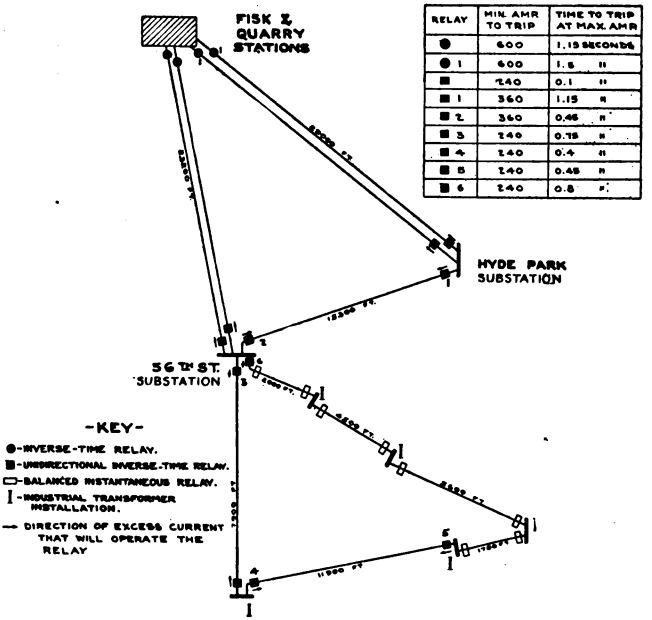
Digitized by Google

ferential relays operating on both the 12,000-volt and the 4000-volt oil switches. The 4000-volt outgoing-feeder circuits are provided with straight overload relays.

On 9000-Volt, 25-Cycle, to 4000-Volt, 60-Cycle Frequency Changers. Bellows overload relays on both the motor and the generator, each operating its own oil switch.

Setting of Relays and Experience

Generators. The balanced relays on generators are, like all the other balanced relays on the system, set for instantaneous



RELAY	MIN. AMR TO TRIP	TIME TO TRIP AT MAX. AMR
●	600	1.15 SECONDS
● 1	600	1.5 "
■	240	0.1 "
■ 1	360	1.15 "
■ 2	360	0.45 "
■ 3	240	0.15 "
■ 4	240	0.4 "
■ 5	240	0.45 "
■ 6	240	0.8 "

Fig. 6 b—Typical Protective scheme—Transmission Lines

operation. Since they have been installed, the relays on one of the units have been called upon to operate twice, in each case promptly disconnecting the unit. The benefit of generator reactors and bus-sectionalizing reactors has been apparent a number of times in limiting the extent of the disturbance resulting from a line break-down close to the station. Previous to the installation of such reactors, cable breakdowns occurring within half a mile (0.8 km.) of the station usually caused fairly widespread disturbance and often considerable damage to generators.

Digitized by Google

Lines. The adoption of the line protective devices described resulted from a desire to make the large line investment more productive by operating in parallel as far as practicable, as well as to localize more fully the disturbance resulting from a cable failure. In the case of the station tie lines, the straight inverse-time-element relays frequently opened when either station got a shock due to a line failure. The installation of balanced relays on these two lines has entirely removed this trouble.

On the transmission lines, the aim is to use the induction type

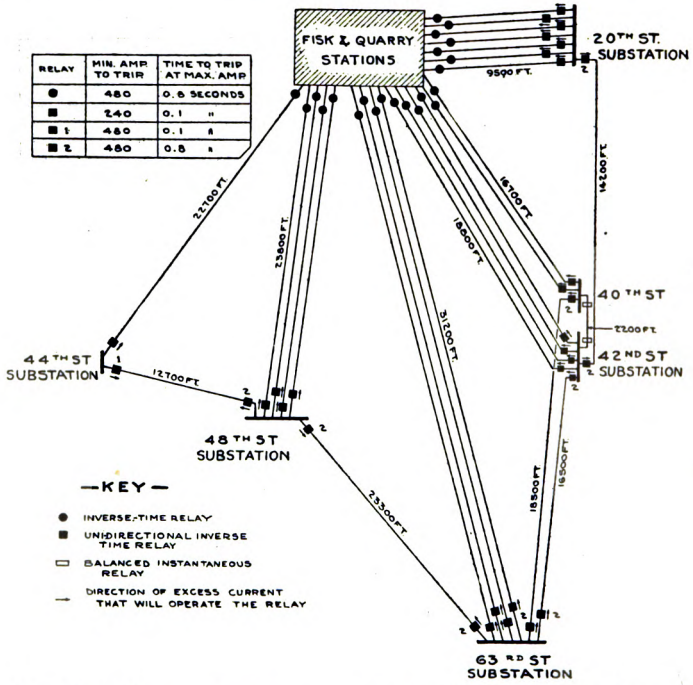


FIG. 6 C—TYPICAL PROTECTIVE SCHEME—TRANSMISSION LINES

of relays in all cases where their satisfactory use does not require the time setting at the station to be too high, and it was generally considered that this maximum setting should not materially exceed two seconds. In the case of ring-connected lines, where the succeeding relays in each link, counting toward the station, must have an increasing time element, the use of these relays only, would in many cases, require a setting in excess of the two second limit. It is obvious that the difference in time setting between any two successive relays in the series

Digitized by Google

must be equal to the time required for the oil switch to fully break the circuit after the relay contact has closed, plus a safe margin, and this, with the speediest apparatus, is approximately

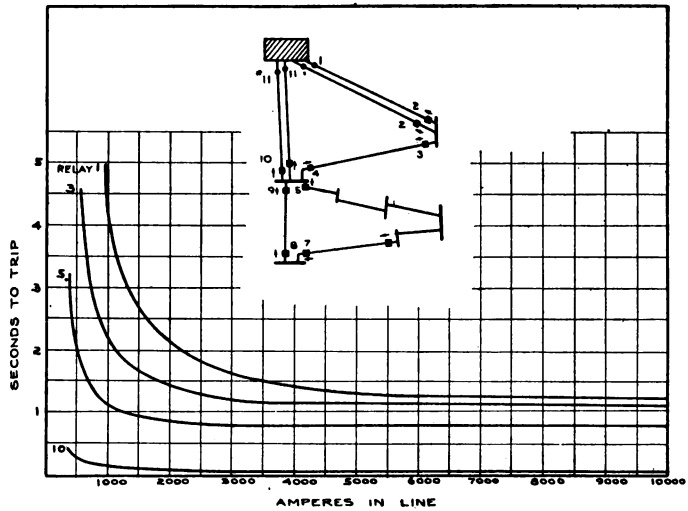


FIG. 7 A—CURRENT-TIME CURVES OF RELAYS

three-tenths of a second. In order, then, to keep down the total number of such relays in series in a ring of many links and thus to prevent the above time limit from being exceeded, the

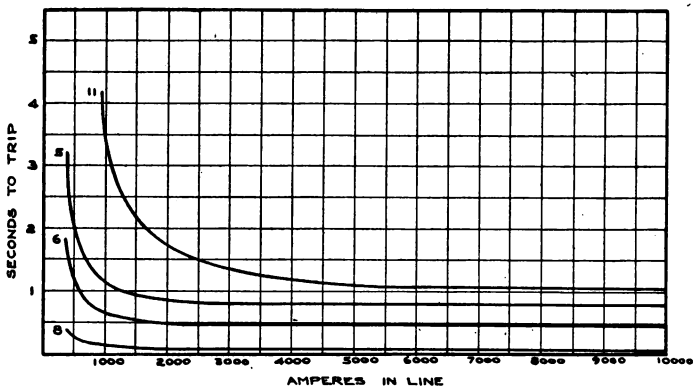


FIG. 7 B—CURRENT-TIME CURVES OF RELAYS

shortest lengths in the ring are provided with balanced relays and pilot wires. The illustrations in Figs. 6A, 6B and 6C show typical installations of relays on a few sections of the system.

Digitized by Google

The data of the settings are also given. The current-time curves of a set of uni-directional relays in a ring are given in Figs. 7A, 7B, 7C and 7D and show clearly how the selectiveness of operation is obtained at all current values. It will be noted

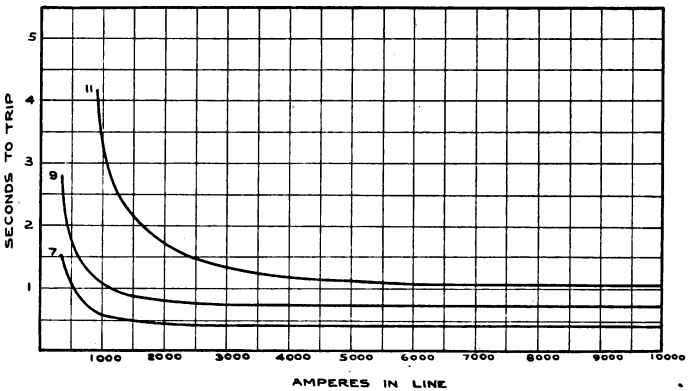


FIG. 7 C—CURRENT-TIME CURVES OF RELAYS

in Fig 6A that in the case of the line to Lake View substation which loops through an industrial installation, the rule of applying the balanced relays to the short length has not been followed. In cases like these the preference for the balanced relay is given

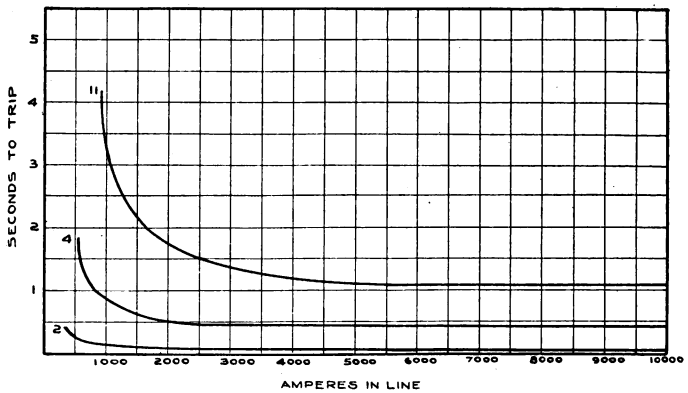


FIG. 7 D—CURRENT-TIME CURVES OF RELAYS

to the section nearest the generting station, even though this section may not be the shortest, the reason being that the balanced relay, having a practically zero time setting, would disconnect the line in case of a short circuit close to the

Digitized by Google

station more promptly than would a relay with a definite-minimum time setting.

Substations. The bellows overload relays on the high-tension side of substation units are set to operate at a minimum flow of approximately two and a half times rated current, to operate in two seconds on three and a half times, and instantaneously on five times rated current. On synchronous converters the speed limit is set at 15 per cent over speed. Differential relays

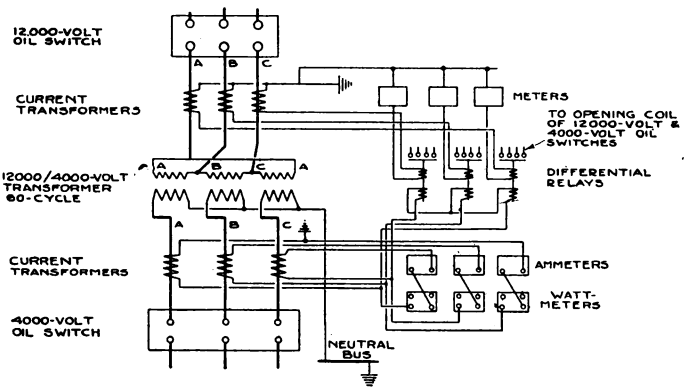


FIG. 8—DIFFERENTIAL RELAY ON SUBSTATION TRANSFORMER

on substation transformers are arranged for instantaneous operation and are shown diagramatically in Fig. 8. The relays on the 4000-volt feeders are of the instantaneous type and set to trip at three times normal load.

There is a considerable number of minor installations of protective relays on the system not covered in the above, but for sake of brevity and because they have no features of special interest they have here been omitted.

Digitized by Google

Digitized by Google

To be presented at the 331st Meeting of the American Institute of Electrical Engineers, Schenectady, N. Y., April 13, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

COOLING OF OIL-IMMERSED TRANSFORMER WINDINGS AFTER SHUT-DOWN

BY V. M. MONTSINGER

ABSTRACT OF PAPER

The 1916 A. I. E. E. Rules require that the temperature rise of transformer windings be observed by the resistance method. Since the measurement of resistance usually requires considerable time, there is always a drop in temperature between the instant of shut-down and the time of observing this resistance measurement. There are three general methods of determining the temperature at shut-down. These are:

1. To take a cooling curve and extrapolate back to the instant of shut-down.
2. To use an arbitrary correction.
3. To calculate the rate of cooling. The usual theoretical formula for calculating the cooling of a body is not in a convenient form for practical use. Furthermore, the conditions in a transformer are generally such that it would be difficult to apply. However, it is shown in the paper that the cooling of oil-immersed transformer windings, for a limited time (four or five minutes) after shut-down, is approximately a function of the watts per lb. of copper, and that when it is necessary to make calculations, more accurate results can be obtained by this partially empirical method than by attempting to use the theoretical formula.

Under "Conclusions", the general advantages and disadvantages of each method are given.

In the Appendix are developed certain formulas used in the paper.

INTRODUCTORY

IT IS standard practise today to rate electrical apparatus at its maximum continuous capacity. When the rating is limited by temperature (as most transformers are) the insulation or some part of it is operating close to the danger point. For this reason, it is important to know more accurately the average temperature of the windings than it has been in the past when it was the practise to make the temperature guarantee for two different loads; namely, full-load followed by a short-time overload.

The A. I. E. E. Standardization Rules recognize three general

Manuscript of this paper was received March 16, 1917.

Digitized by Google

methods of determining the temperature of electrical apparatus. These are:

Method No. 1: Thermometer method (Section No. 345).

Method No. 2: Resistance method (Section No. 348).

Method No. 3: Embedded temperature-detector method (Section No. 352).

Due to the fact that transformer windings are usually inaccessible for thermometers and less accessible for temperature detectors than are generators, motors, etc., the A. I. E. E. Rules (Section No. 351) specifies that the temperature of windings of transformers is always to be ascertained by method No. 2—resistance method. However, it is stated that in the application of method No. 2, careful thermometer measurements must also be made whenever practicable to increase the probability of revealing the highest observable temperature. The use of thermometers in determining the "hottest spot" in the windings of transformers applies almost exclusively to air-blast or natural draft rather than to oil-immersed transformers.

The foot note to Section No. 348 in the A. I. E. E. Standardization Rules states:

> Whenever a sufficient time has elapsed between the instant of shut-down and the time of the final temperature measurement to permit the temperature to fall, suitable corrections shall be applied, so as to obtain as nearly as practicable the temperature at the instant of shut-down. This can sometimes be approximately effected by plotting a curve, with temperature readings as ordinates and times as abscissas, and extrapolating back to the instant of shut-down. In other instances, acceptable correction factors can be applied. In transformers of 200 kv-a. and less, the measured temperature shall be increased one degree for every minute between the instant of shut-down and the time of the final temperature measurement, provided this time does not exceed three minutes.
>
> In cases where successive measurements show increasing temperatures after shut-down, the highest value shall be taken.

In observing the temperature of transformers by means of change in resistance, there usually is a sufficient lapse of time to permit an appreciable drop in temperature. In practise this drop ranges from a fraction of a degree to several degrees per minute, hence it becomes highly important to know the extent of it.

While the cooling-curve method is fairly reliable, commercially it is not always practicable. Furthermore, it is desirable, from the manufacturer's standpoint, to have some method whereby for designing purposes, one can predetermine the fall in temperature for various intervals of time which a cooling

Digitized by Google

curve does not give until after the machine has been designed and tested.

It is the purpose of the writer to discuss from a theoretical standpoint the cooling of oil-immersed transformer windings after load has been removed, and to show that the cooling in degrees of the average type of oil-immersed winding for the first four or five minutes after shut-down is approximately a function of the loss expressed in terms of watts per lb. of copper. In other words, it is shown that for practical purposes, the cooling can be calculated for a limited time after shut-down without considering either the thermal capacity of the insulation or the initial temperature rise of the winding. If we can neglect these two factors, it is obvious that the process of calculating the cooling is greatly simplified as compared with the usual method of calculations by considering the thermal capacity of the mass and its initial temperature rise.

It is the difficulty, for the usual transformer winding complicated by oil ducts, etc., of determining accurately the above two factors, especially the initial rise, that makes it difficult to calculate the cooling by the usual theoretical formula. For instance, for a transformer winding with numerous oil ducts, the temperature of the surrounding medium or ambient temperature is that of the oil in the ducts and of the oil surrounding the coil stack. While the oil surrounding the coil stack no doubt remains fairly constant for the first five minutes after shut-down, the oil in the ducts is moving through, just after shut-down, at the same rate it was before shut-down. Since this moving oil is influenced by the temperature of the coils, and since the temperature of the coils is decreasing after shut-down, the temperature of this oil in the ducts is also decreasing.

In other words, if we consider the temperature of the oil in the ducts as the ambient temperature, we have here a constantly decreasing ambient temperature which would be troublesome to deal with in making calculations. On the other hand, if we consider the oil surrounding the coil stack (*i.e.*, neglecting that in the ducts) as the ambient temperature, we must take into consideration the thermal capacity of the oil in the ducts. This also would be difficult to do because as stated above, this oil is not stationary. However, in the case of a single coil immersed in oil where conditions are not complicated by oil ducts, fairly accurate calculations can be made by the use of the usual theoretical formula.

Digitized by Google

Calculation of Cooling by Theoretical Formula

When loss of heat energy is proportional to temperature rise the cooling of a body takes place according to a "die-away" curve which is expressed by the formula

$$\theta_t = \theta_0 \epsilon^{-\beta t} \qquad (1)$$

in which

θ_t = temperature rise at any time t of the body over its ambient temperature.
θ_0 = initial temperature rise or rise at shut-down.
ϵ = base of Naperian logarithms.
β = time constant.

Equation (1) is based on the assumption that the rate of heat dissipation, *i.e.*, the cooling, is proportional to the temperature rise. It is shown later that this assumption is not quite correct for oil-immersed windings, for the reason that the rate of heat dissipation is seldom if ever a direct function of the temperature rise. A formula is developed in the Appendix for the condition where the loss of heat is not proportional to the temperature rise, but equation (1) is usually accurate enough for practical purposes.

Equation (1) may be put into a more convenient form by changing signs, adding θ_0 to both sides and then putting $(\theta_0 - \theta_t) = \theta$, where θ is the cooling in deg. cent. We now have

$$\theta = \theta_0 (1 - \epsilon^{-\beta t}) \qquad (2)$$

Differentiating equation (1) with respect to time, we find that when $t = 0$ the time constant β is

$$\beta = \frac{\text{initial rate of cooling}}{\text{initial temperature rise}}$$

Initial Rate of Cooling

The "initial rate of cooling" depends upon the thermal capacity of the body being cooled. Transformer windings consist mainly of copper and fibrous insulation. The thermal capacity or energy in joules required to raise the temperature of copper one deg. cent. equals the weight of copper times the number of grams in one pound times the specific heat of copper times the number of joules in one calorie $= W \times 453.6 \times 0.0935 \times 4.185 = 177.5\ W$, where W is the weight in pounds. The

Digitized by Google

rate of heat storage in copper which is the same as the "initial rate of cooling" in degrees per minute is $\frac{60 \times \text{watts}}{177.5\ W} = 0.338\ W_c$

where W_c is the watts per pound of copper.

The thermal capacity of most insulating materials by *volume* ranges from about $\frac{1}{3}$ to $\frac{1}{2}$ that of copper. Tests indicate that for most impregnated insulations the value of $\frac{1}{2}$ is more nearly correct. For an insulated copper conductor or coil then, the initial rate of cooling $= 0.338\ W_c \frac{2_a}{A + a} = \frac{0.676\ a\ W_c}{A + a}$ in which

a = the cross-sectional area of the copper and

A = the cross-sectional area of the copper plus the insulation.

We now have

$$\beta = \frac{0.676 \frac{a\ W_c}{A + a}}{\theta_0}$$

The above expression, of course, does not hold when the average temperature of the insulation is considerably lower than the temperature of the copper. This condition, however, seldom if ever exists except probably for a few end turns (exposed to line voltage) in the windings of a transformer.

Initial Temperature Rise

It has been shown* that the temperature rise (same as "initial temperature rise" when considering cooling curves following constant conditions) of a tank surface in a gas (air) cooled by convection varies as the 0.8 power of the loss through a limited range of temperatures. This, or a similar law, seems to be universally true for all types of oil-immersed windings, although the exponential value depends to some extent upon the thicknesses of insulation. The reason for this is that the temperature drop from copper to oil is composed of two components,— surface drop and drop through the insulation, the former of which changes more rapidly with a change in temperature than the latter. (Hereafter in referring to temperature drop through insulation, it will be expressed in deg. cent. drop when there is a flow of one watt per sq. in. through a distance of one inch of material. This is generally written "deg. per watt per in.[3]"

*Proc. A. I. E. E., Montsinger, April, 1916.

Digitized by Google

when considering the temperature drop through a definite thickness and "deg. per watt per in.^{2}" when considering the temperature drop of a surface.)

Referring to Fig. 1, it will be noted that as the temperature increases from approximately 33 deg. in lower curve to 75 deg. cent. in upper curve the surface drop from insulation to oil decreases from 6.7 deg. to 4.7 deg. per watt per in.^{2}. Practically the same decrease is noticed in the sur-

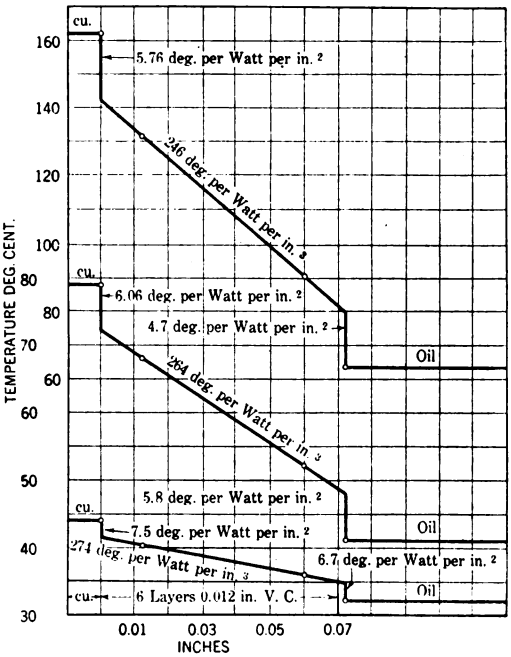


FIG. 1—SURFACE AND INSULATION TEMPERATURE DROPS

face drop from copper to insulation, while the drop through the insulation, for a change in average temperature from about 38 deg. to 110 deg. cent., is only decreased from 274 deg. to 246 deg. per watt per in.^{3}. The thickness of this insulation, 72 mils (.183 cm.) is considerably greater than that used on most transformer windings, so that this large drop through the insulation does not necessarily represent conditions as found in practise. The The insulation, composed of 0.012-in varnished cambric strips one-in. in width, wound on butt joint, was made of sufficient

Digitized by Google

thickness to obtain an appreciable temperature drop. By drawing a straight line through two internal temperature points, obtained by thermo-couples, the inner and outer surface temperatures were determined.

It is evident, therefore, that the value of the exponent in the equation of *temperature rise* vs. *loss*, will be less when the greater portion of the total drop is a surface drop than when the greater portion is a drop through insulation.

Fig. 2 shows the value of the exponent (slope of line) to be 0.7 when the suface of a coil is bare, and 0.9 when covered with six layers of 0.012 in. varnished cambric, and also

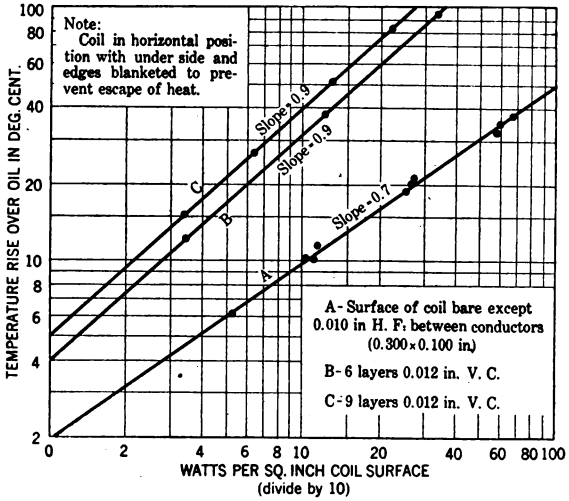


FIG. 2—TEMPERATURE RISE OF OIL-IMMERSED WINDING

0.9 with nine layers of varnished cambric. It is shown later that the value of the exponent is approximately 0.7 when a coil has a light insulation such as is generally used in practise.

It has been shown by Dr. Langmuir* that the "convection" of heat from a surface in a gas consists essentially of conduction through a film of stationary gas 0.177 in. (.045 cm.) over the surface. A stationary film no doubt exists when heat energy is transferred from a surface to liquids. Very little, however, is known about this film, except that it exists, and for this reason

*Physical Review May, 1912.
Am. Electro Chem. Soc. April, 1913.

Digitized by Google

we have to depend upon experimental observations for determining its thickness and its effect on the temperature rise.

Thickness of Oil Film

The best data at hand indicate that the thermal resistivity of transformer oil is approximately 250 deg. cent. per watt per in.^{3}. Accepting that this figure as correct (which may or may not be very accurate) according to the surface drops in Fig. 1, (approximately 6 deg. per watt per in.^{2}.) the indications are that the thickness of the stationary film of oil is $6/250 = 0.024$ in. (.061 cm.) This value, however, should be considered as merely approximate, since it may vary somewhat for different conditions. Further work is required along this line to establish more accurate data.

Thermal Resistivity of Insulation

According to Fig. 1, the average thermal resistivity of the insulation is 261 deg. per watt per in.^{3}. However, the thermal resistivity of insulation as applied to electrical apparatus is by no means a constant value but may vary anywhere from about 200 deg. cent. for solid to 500 deg. cent. per watt per in.^{3}. for loosely wound insulation containing oil or air spaces between layers. Generally speaking, about 250 deg. per watt per in.^{3}. seems to be the value most commonly found* in practise for compact insulation coverings.

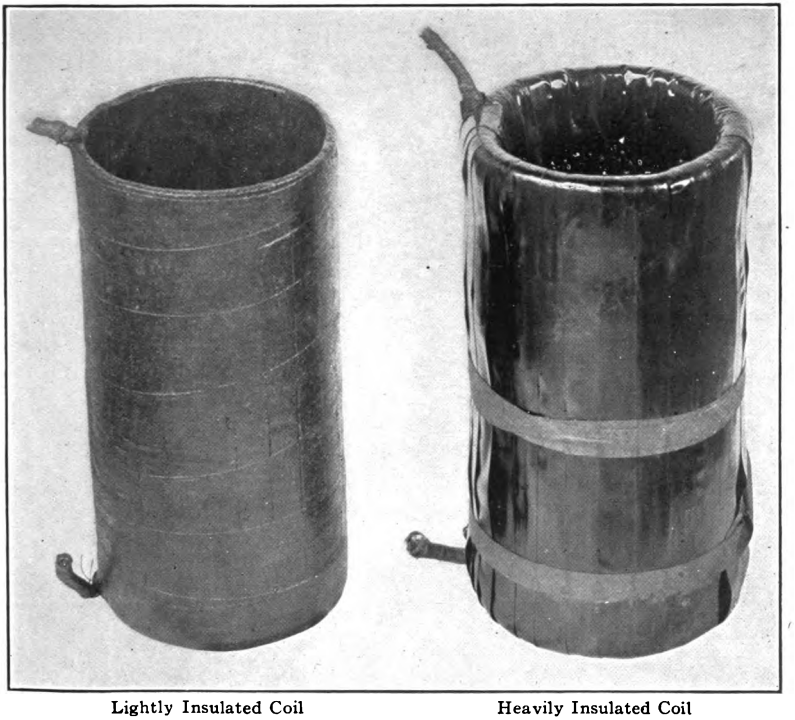
Rate of Cooling as Affected by Thermal Capacity and by Initial Temperature Rise

It is obvious from the form of equation (2) that for a given initial temperature rise θ_0, for a given mass of copper and a given loss, the greater the mass of insulation, the slower will be the rate of cooling. However, it should be *remembered* that in order to have the same initial temperature rise when insulation is increased, on, say a transformer winding, it is necessary that the watts per unit area exposed to the cooling medium be decreased sufficiently to compensate for the increase in temperature due to the added insulation. Otherwise an increased temperature rise will result.

Insulation is usually used in transformer windings, in two ways; (1) by placing it on individual strands or conductors,

*See paper and discussion on Heat Paths in Elec Machinery, Symons and Walker, British Inst. of E. E., November, 1911.

Digitized by Google



Lightly Insulated Coil Heavily Insulated Coil

[MONTSINGER]

FIG. 3—COILS USED IN DETERMINING EFFECT OF COIL INSULATION ON COOLING AFTER SHUT-DOWN

See Figs. 4 and 5 for Cooling Curves

Digitized by Google

Digitized by Google

and (2) by placing it on individual coils. When the conductor insulation is increased, although the watts per unit area of surface is decreased, the temperature rise is generally increased. When the coil insulation is increased, the surface loss is not usually affected and hence it follows that the temperature rise is always increased.

On the whole, it seems fair to assume that when insulation is added to transformer windings, the surface loss per per unit area is not usually reduced sufficiently to neutralize the increased drop established in the insulation and an increased temperature rise results. Accepting this assumption, it is

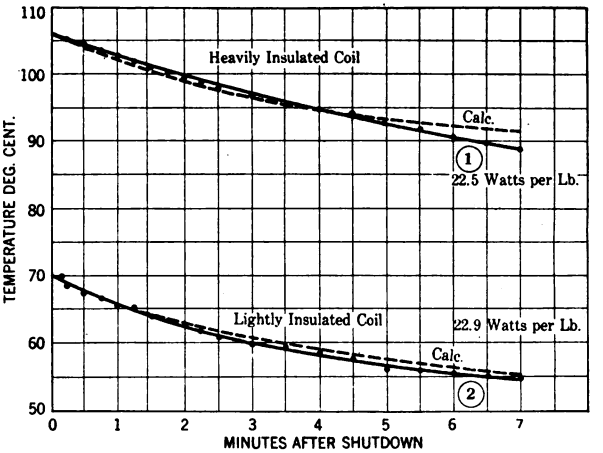


FIG. 4—COOLING OF OIL-IMMERSED WINDINGS SHOWN IN FIG. 3 (AVERAGE OIL APPROXIMATELY 55 DEG. CENT.)

obvious that when insulation is added to a winding, (although the rate of cooling immediately after shut-down is decreased), there must be a time when not only the *rate* but the *actual cooling* in degrees of this winding is greater than that for a winding with a lesser amount of insulation. This same effect is had when a transformer has very complicated oil ducts of such a nature to restrict the oil circulation and cause an increase in the temperature rise. For instance, it is obvious that for a given loss per lb. of copper, any factor which makes it more difficult for the coil to cool, and hence causes an increase in the temperature rise, also causes the rate of cooling to be

Digitized by Google

less for a short time after shut-down. The duration of this time seems to be from one to three minutes. Finally, it may be stated as follows:

"Any factor or set of factors which causes an increase in temperature rise for constant conditions, also causes a decrease in the rate of cooling for a short time after shut-down."

Of course, after a time, the cooling necessarily becomes greater.

For example, the effect of increasing the insulation on a coil (where the surface loss is not changed) on its rate of cooling is very well illustrated in Figs. 4 and 5. These curves give the

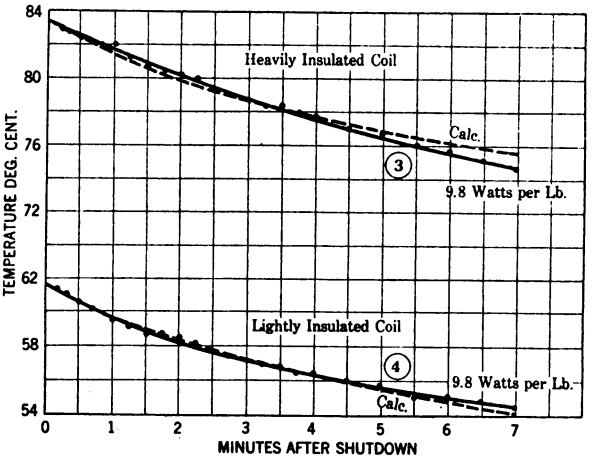


FIG. 5—COOLING OF OIL-IMMERSED WINDINGS SHOWN IN FIG. 3 (AVERAGE OIL APPROXIMATELY 50 DEG. CENT.)

cooling of two coils under identical conditions, excepting that one had heavy insulation and the other light insulation. Both coils wound on a foundation ring or cylinder, 40 mils in thickness and consisted of 0.2×0.055-in. edge-wound conductor with a 10.5-mil cotton covering, and over both coil surfaces were wound 15 mils of binding tape. Fifteen to eighteen layers of 0.012 in. v.c. was then wrapped on both the inside and outside surface of one coil, while the other coil was given no extra insulation (see Fig. 3). We might designate the insulation on the coils as "heavy" and "light". According to curves in Figs. 4 and 5 their cooling is as follows:

Digitized by Google

Insulation on coil	Watts per lb. cu.	Approx. initial temp. rise	Cooling in deg cent.						
			1	2	3	4	5	6	7 min.
Heavy.....	22.5	56°	3.6	7.2	10.3	12.9	15.2	17.3	19.2
Light.....	22.9	20°	4.9	8.1	10.8	12.8	14.1	15.3	16.0
Heavy.....	9.8	33.5°	1.8	2.4	4.6	5.8	6.9	7.9	8.8
Light.....	9.8	11.5°	2.0	2.4	4.5	5.3	6.1	6.7	7.2

The above shows that the cooling of the heavily insulated coil is at first less and then finally becomes greater than the cooling of the lightly insulated coil. The cooling of both coils, however, is approximately the same until four or five minutes after shut-down. The amount of insulation on the heavily insulated coil is somewhat exaggerated as compared with practise, but it illustrates the point in mind.

Derivation of Practical Formula for Correcting Back to Shut-Down

The question, what is the rate of cooling for various watts per pound of copper, naturally arises. This can be calculated by the use of equation (**2**) providing the initial temperature rise and the thermal capacity of the mass is given for a typical coil. As stated before, the true initial rise of windings over oil is difficult to obtain in an actual transformer, but can be determined for a single coil operating under a condition that the surrounding oil temperature can be observed. According to the above reasoning, the cooling of this coil for a given loss and for a limited time should be approximately the same when operating singly as when operating in a group of coils.

In Fig. 6 is shown on logarithmic paper the temperature rise for various watts per square inch coil surface obtained by tests for constant conditions on a single transformer coil immersed in oil. A diagram is given showing the size of conductor (used in the coil) and its insulation. This line of temperature rise vs. loss, shows that the temperature rise varies as the 0.705 power of the loss. If we let θ_0 equal the temperature rise for the above referred to coil, the equation of the line is

$$\theta_0 = K W_s^{0.705} \qquad (3)$$

Digitized by Google

n which

K = constant = 5.2

W_s = watts per sq. in. of surface (divide by 10).

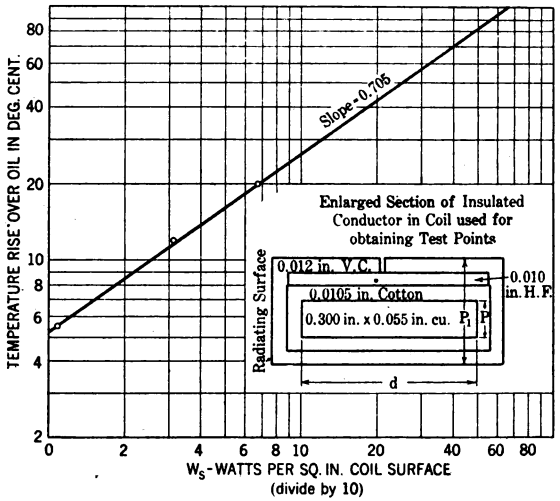


FIG. 6—TEMPERATURE RISE OF OIL-IMMERSED WINDING

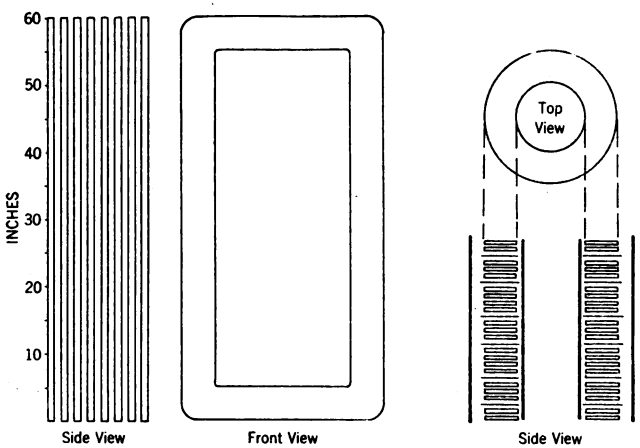


FIG. 7—SKETCH OF WINDINGS USED FOR COOLING CURVES IN FIGS. 8 AND 9

At 25 deg. cent. the surface loss of a coil with rectangular or square conductors is expressed by

$$W_s = 3.47\ C^2\ d\ n\ s\ 10^{-7} \qquad (4)$$

Digitized by Google

in which

W_s = $R I^2$ watts per sq. in. surface (neglecting edges of coil but including conductor insulation).

C = current density in amperes per sq. in.

d = depth of bare conductor in inches, in direction of flow of heat.

n = number of conductors in direction of flow of heat.

s = conductor space factor at right angles to flow of heat.

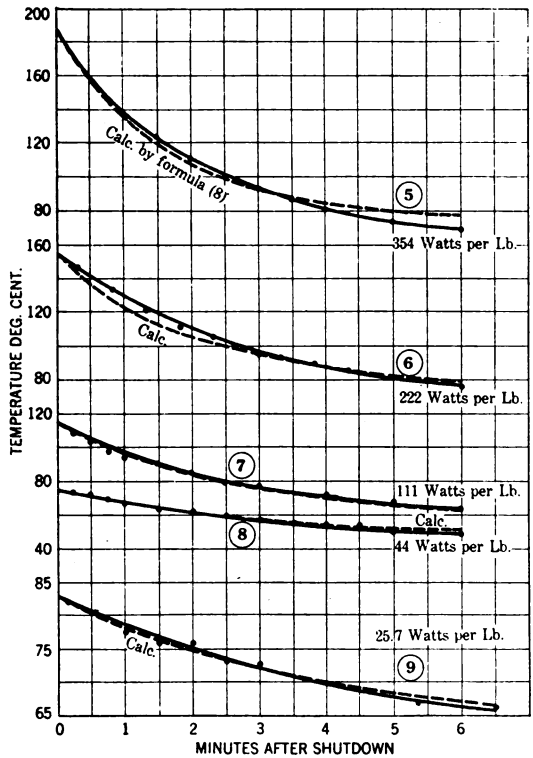


FIG. 8—COOLING OF OIL-IMMERSED DISK WINDINGS SHOWN IN FIG. 7

For coils with round conductors, the value of W_s in (4) is decreased in the ratio of 4 to π, or

$$W_s = 2.725 \times 10^{-7} C^2 d n s \qquad (5)$$

At 25 deg. cent. the $R I^2$ watts per lb. of bare copper (W_c) is

$$W_c = 2.16 C^2 10^{-6} \qquad (6)$$

Digitized by Google

Combining equations (**3**), (**4**) and (**6**), we have

$$\theta_0 = 7.27\ (W_c\ d\ n\ s)^{0.705} \qquad (7)$$

Substituting the above value of θ_0 in equation (**2**)

$$\theta = 7.27\ (W_c\ d\ n\ s)^{0.705}\left(1 - \epsilon^{-\frac{0.0928\ \frac{a\ Wc\ t}{A\ +\ a}}{(Wc\ d\ n\ s)\ 0.705}}\right)$$

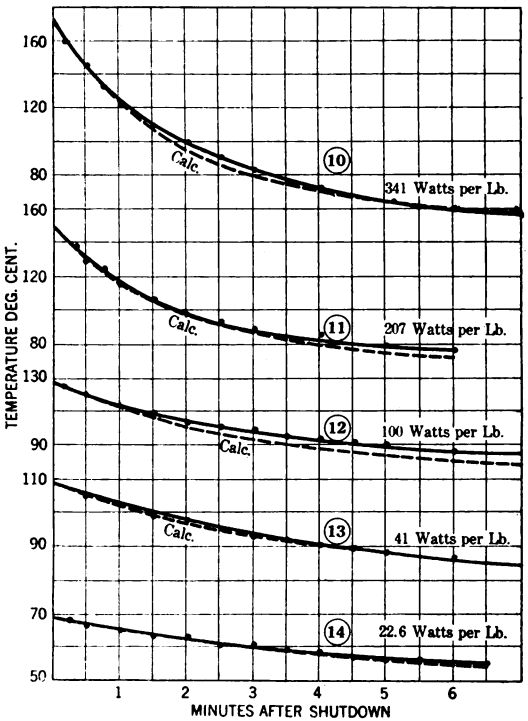


FIG. 9—COOLING OF OIL-IMMERSED RECTANGULAR WINDINGS SHOWN IN FIG. 7

Putting (from dimensions of conductor in Fig. 6)

$$\begin{aligned} d &= 0.3 \\ n &= 1 \\ s &= 0.5 \\ a &= 0.0165 \\ A &= 0.038 \end{aligned}$$

Digitized by Google

and changing 0.705 to 0.7 and increasing the value 7.27 to 7.35 (to compensate for reduction of 0.705 to 0.7), we have

$$\theta = 1.95\ W_c^{0.7}\ (1 - \epsilon^{-0.106\ W_c^{0.3} t}) \qquad (8)$$

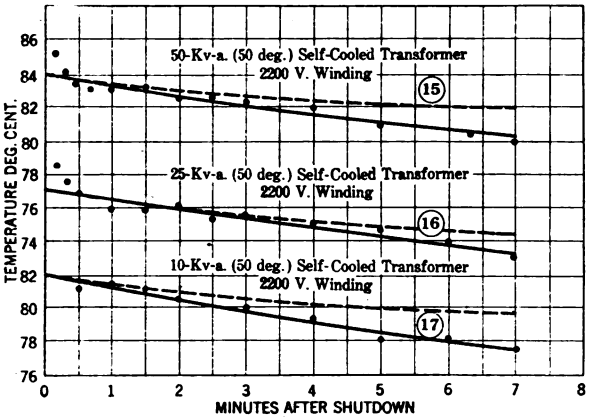


FIG. 10—COOLING OF DISTRIBUTING TRANSFORMERS

in which

θ = cooling in deg. cent.

W_c = watts per lb. of bare copper.

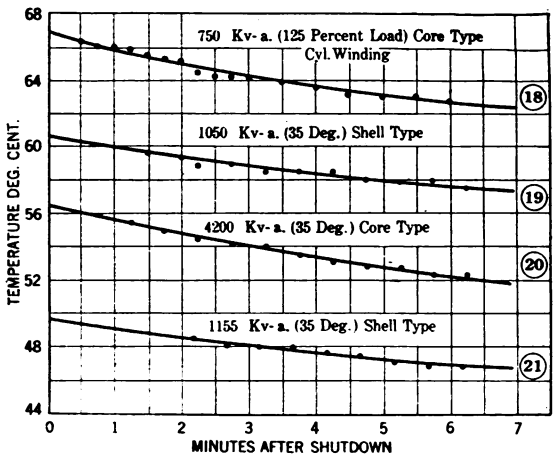


FIG. 11—COOLING OF AIR-BLAST TRANSFORMERS (AIR SHUT OFF)

at 75 deg. cent., $W_c = 2.577\ C^2 \left(1 + \frac{e}{100}\right) 10^{-6}$

e = eddy current loss in per cent of $R\ I^2$.

t = time in minutes after shut-down.

Digitized by Google

In Fig. 13 are plotted, from equation (**8**), the degrees cooling vs. different values of W_c for 1, 2, 3, 4, 5, 6 and 7 minutes after shut-down.

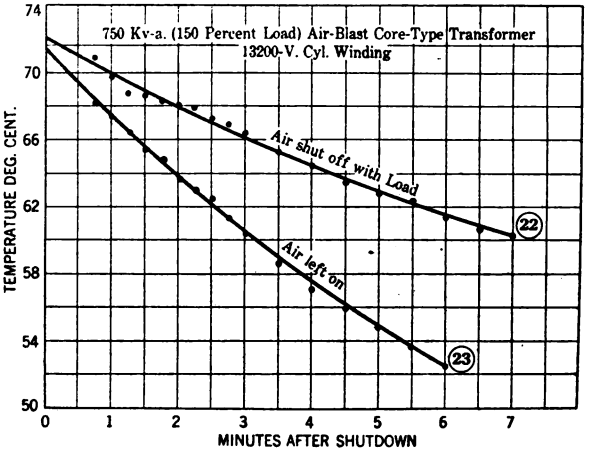


FIG. 12—COOLING OF AIR-BLAST TRANSFORMER

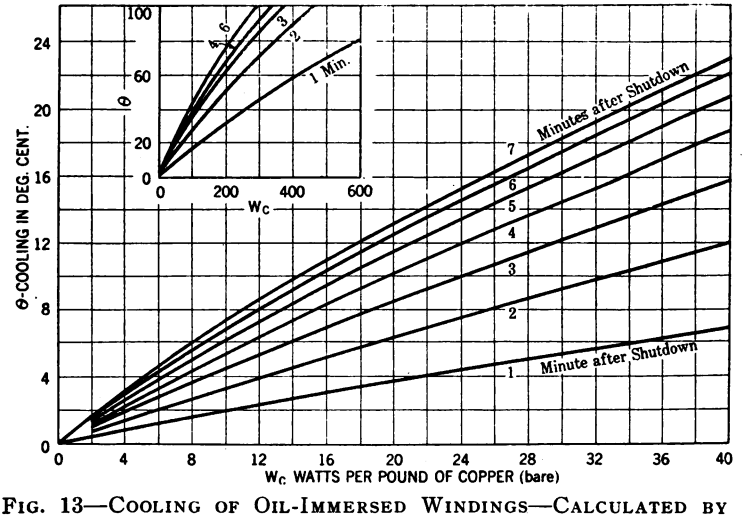


FIG. 13—COOLING OF OIL-IMMERSED WINDINGS—CALCULATED BY FORMULA

Table 1 gives the variation in degrees centigrade (+ or −) that these curves differ from the cooling found by tests, on various types of oil-immersed windings.

Digitized by Google

TABLE I.

COMPARISON OF COOLING BY TEST OF OIL-IMMERSED WINDINGS WITH COOLING CALCULATED BY FORMULA (8).

Self-or water-cooled	Kv-a.	Style of winding	Deg. cent. Variation of test from calculated cooling			
			2 minutes after shut-down		4 minutes after shut-down	
			+	—	+	—
Self	200	Cyl.	0.5		0.8	
"	400	Disk		0.5		0.7
"	1000	Cyl.	0	0	0	0
"	750	Disk	0.5		0.8	
Water	3000	Disk	0		0.2	
"	2500	Cyl.		0.5		0.9
Self	200	Cyl.	0.8		1.1	
"	433	Disk	0.5		0.4	
"	400	Disk		0.7		0.8
"	135	Cyl.	0.1		0.1	
"	750	Disk	0	0	0	0
Water	450	Disk		0.5		0.4
"	2000	Disk	0.0		0.9	
Self	300	Cyl.	0.2		0.6	
"	300	Disk	0.4		1.0	
Water	1000	Disk		0.7		0.8
"	900	Cyl.		0.2		0.8
"	750	Disk	0.6		0.7	
"	750	Disk		0.2		0
Self	1000	Cyl.	0.3		0.6	
"	750	Cyl.		0.5	0.1	
Water	5500	Rectangular	0	0	0.5	
"	5500	"	0.2		0.3	
"	6000	"	0	0	0.5	
"	6000	"	0.3		0.5	
Self	46	Regulator	0.5		0.8	
"	62.5	"		0.1		0.2
"	8.6	"	0.3		0.7	
"	17.25	"		0.3		0.4
"	62.5	"	0	0	0.7	
"	8.6	"	0.2		0.9	
"	46	"	0.4		0.7	

General Conclusions

Regarding the three general methods of determining the temperature at the instant of shut-down, as mentioned in the "Abstract", the following may be said of each:

1. *Cooling Curve Method.* Practise has shown that generally this method is fairly reliable. In some cases, however, it is liable to error, due to the difficulty of being able to extrapolate back correctly. This is true when considerable time is required in obtaining the initial readings or when these first readings are

Digitized by Google

influenced by inductance in the windings. At any rate, commercially, this method is not always practical due to the increased time required.

2. *Arbitrary Correction.* The advantages of this method are simplicity and ease of application. The disadvantage is that it is liable to error. Generally speaking, for maximum rated water-cooled transformers, the copper loss will vary from about 6 to 25 watts per lb. If an arbitrary correction of say 2 deg. cent. per minute is adopted, the following errors (plus or minus) are liable to be had for this particular type of apparatus.

Minutes after shut-down	Cooling in deg. cent. by curves in Fig. 13		Cooling by arbitrary correction of 2 deg. cent per minute	Max. error
	6 watts per lb.	25 watts per lb.		
2	2.0 deg.	8.0 deg.	4 deg.	4 deg.
4	3.5 deg.	12.5 deg.	8 deg.	4.5 deg.

In cases where machines operate on short-time over-loads, or on duty-cycle operation, the error would naturally be greater than the above.

Again this method might put a premium on using high current densities.

Providing the time does not exceed four minutes after the instant of shut-down, the following, however, seems to be about the general average rates of cooling for

(a) Air-blast transformers (air shut off)..... $\frac{1}{2}$ deg. cent. per min.
(b) Distributing transformers (100 kv-a. and less) $\frac{1}{2}$ " " " "
(c) Self-cooled transformers (except (b))..... $1\frac{1}{2}$ " " " "
(d) Water-cooled transformers..... 2 " " " "

3. *Calculation of Cooling.* (By formula (**8**) or by curves in Fig. 13). The advantage of this method is that it is fairly reliable and simple in application. In order to apply the formula, it is necessary only to know the watts ($R I^2$ + eddy loss) per lb. of copper.

The disadvantage of this is that in order to apply the formula or curves (Fig. 13) plotted from the formula, the current density and eddy loss must be known, which cannot be determined by test.

Digitized by Google

APPENDIX

A.—Cooling After Shut-Down When Loss of Heat is Proportional to Temperature Rise

Assuming that the cooling is proportional to temperature rise, the following equation results

$$\frac{d\,\theta}{d\,t} = \beta\,\theta$$

The solution of this is

$$\theta\,t = \theta_0\,\epsilon^{-\beta\,t} \qquad (1)$$

where

θ_t = temperature rise at any time t after shut-down.
θ_0 = temperature rise at shut-down.
β = time constant.

At the time of shut-down the rate of cooling in deg. cent. per minute of copper is 0.338 W_c, where W_c is the watts per pound. Differentiating (**1**).

$$\frac{d\,\theta_t}{d\,t} = \beta\,\theta_0\,\epsilon^{-\beta\,t} \quad \text{When } t = o, \quad \epsilon^{-\beta\,t} = 1$$

$$\frac{d\,\theta_t}{d\,t} = \beta\,\theta_0 = 0.338\ W_c$$

or

$$\beta = \frac{0.338\ W_c}{\theta_0} = \frac{\text{initial rate of cooling}}{\text{initial temperature rise}}$$

B.—Cooling After Shut-Down When Loss of Heat is Not Proportional to Temperature Rise

For th s condition we have

$$\frac{d\,\theta}{d\,t} = \beta\,\theta^n$$

$$\int_{\theta_t}^{\theta_0} \frac{d\,\theta}{\theta^n} = \beta \int_0^t d\,t$$

$$\frac{\theta_0^{-n+1}}{1-n} - \frac{\theta_t^{-n+1}}{1-n} = \beta\,t + C$$

when $t = 0$, $\theta_0 = \theta_t$ & $C = 0$

$$\theta_t^{-n+1} = \theta_0^{-n+1} - \beta\,t\ (1-n)$$

Assuming that $n = \frac{1}{0.7} = 1.43$

$$\theta_t = \left[\frac{1}{\left(\frac{1}{\theta_0}\right)^{.43} + 0.43\ \beta\,t}\right]^{2.33} \qquad (3)$$

Digitized by Google

C.—Surface Loss of Coil With Rectangular (or Square) Conductor

Let W_s = Watts per sq. in. surface, (both sides).
d = Depth of conductor in inches (bare).
n = Number of conductors deep.
s = Space factor = $\frac{P}{P_1}$
P = Width of conductor (bare) in inches at right angles to flow of heat.
P_1 = Width of conductor (insulated) in inches.
I = Current in amperes.
C = Current density in amperes per sq. in. = $\frac{I}{d\,P}$
l = length of conductor.

Now
$$W_s = \frac{\text{Loss in watts} \times s}{\text{Area of coil in sq. in.}}$$
$$= \frac{R\,I^2 \times s}{2\,P\,l}$$

Based on 0.6935 microhm per in. cube at 25 deg. cent., resistance of copper (conductor) = $\frac{0.008322}{d\,p}$ ohms per 1000 ft. length.

Then
$$W_s = \frac{\frac{0.008322\ I^2\ s}{d\,p}}{\frac{2p\ 12000}{n}}$$

Multiplying and dividing by d

$$W_s = \frac{3.47\ x\ 10^{-7}\ I^2\ d\ n\ s}{d^2\ p^2}$$
$$= 3.47 \times 10^{-7}\ C^2\ d\ n\ s \qquad (4)$$

D.—Watts per Pound of Copper

The weight in pounds of copper per 1000 ft.
= 3858 × cross section in sq. in. = 3858 $d\ p$.

$W_c = \frac{R\,I^2}{3858\,d\,p}$ where R = resistance in ohms per 1000 ft.

$$W_c = \frac{\frac{0.008322\ I^2}{d\,p}}{3858\ d\ p}$$
$$= 2.16 \times 10^{-6}\ C^2 \qquad (5)$$

Digitized by Google

REPORT OF THE JOINT RUBBER INSULATION COMMITTEE—1916

PART I—GENERAL REPORT

Need of Specifications

1. A demand for specifications which will enable purchasers of rubber insulation for wire or cable to secure good material on the basis of competitive bids has existed for many years.

2. In recent years, there has been no difficulty in securing insulation having the dielectric strength, specific resistance, elasticity and mechanical strength required in practise. Indeed, with the possible exception of dielectric strength, these qualities are usually in excess of actual service requirements. There is another quality, namely, permanence, which although equally essential, has not been so easy to obtain.

3. While the physical properties of rubber insulation are susceptible of positive determination by tests which can be made before acceptance by the purchaser, the permanence of insulation can be ascertained with certainty only by actual trial, often at great loss, inconvenience and even danger. It should, therefore, be the aim of specifications to overcome this difficulty and by some indirect means, ensure that the manufacturers supply compounds having the required endurance.

4. This obviously presents a difficult problem, as it requires that some relation be established between permanence and one or more of the properties which are susceptible of test. It has been established by experience that Hevea rubber or the rubber of the Hevea Brasiliensis tree, when properly cured is a superior grade which is entirely satisfactory for electrical insulation of the class under consideration. Hevea rubber may, therefore, be specified with advantage, although certain other rubbers of good quality may thereby be excluded. The rubber has to be Hevea rubber of good quality, the materials associated with it in the compound must be known to be non-deleterious and the compound itself must be well prepared, applied and vulcanized.

Types of Specifications

5. Two types of specifications have been devised to compass these restrictions. The first type of specification proceeds on the assumption that certain physical characteristics are developed to an unusual degree by the use of Hevea rubber, especially the grade known as fine Para. Among the qualities affected by the grade of rubber, and alleged to be useful indications of the presence of Para rubber, are the tensile strength, elasticity and specific electrical resistance. Accordingly some specifications have been issued in which one or more of these qualities is specified

This report has been approved by the Standards Committee, and is published by order of Board of Directors.

Digitized by Google

in an exaggerated degree. Experience has shown that such specifications are ineffective, as the specified physical quality can be obtained either by manipulation of poor compounds or at the expense of permanence in compounds made originally of good materials. In consequence of this, specifications based exclusively on physical tests have fallen into disrepute, but such tests now serve in modified form as adjuncts to other types of specifications.

6. The second type of specification to be considered is that in which a more or less rigid formula for the compound is specified and compliance with it exacted either by inspection during manufacture, or by chemical analysis supplemented by other tests of the finished product. Inspection which will really ensure compliance with such specifications is usually impracticable. Reliance must, therefore, be placed principally upon chemical analysis. Three difficulties at once arise. In the first place chemical analysis cannot directly ascertain the quality of the rubber which has been used in the manufacture of a compound; it can only determine quality by the indirect method of measuring certain characteristic constituents. It is, therefore, necessary to present in the specification, a relation between the desired formula and the chemical findings. The second difficulty is that in the past, chemists have employed diverse methods of analysis which give inconsistent results. It is, therefore, necessary to establish a satisfactory and standard procedure for analysis. The method of analysis must not only yield the information desired, but it must also be practical and capable of yielding uniform results when applied to the same compound by different chemists. In order to secure this uniformity, it is important to describe the methods of analysis in detail. The third difficulty has been the non-uniform interpretation of analytical results.

7. The specification hereinafter presented is of the second or chemical type, in which an endeavor has been made to meet the three objections hitherto urged against such specifications. It contains a table showing the range of analytical results that should be obtained from a good compound containing 30 per cent of high class Hevea rubber, and is supplemented by a detailed analytical procedure. The specification is not complete as given, it being necessary to add appropriate electrical and mechanical test requirements. Examples of complete rubber insulation specifications are cited in Part VI. of this report.

8. The specification should always be used in conjunction with the analytical procedure. The latter will, however, serve for the analysis of any compounds of the 30 per cent Para type with mineral fillers, provided the interpretation is made to correspond.

History of Committee

9. The necessity of purchasing insulated wire under conditions of competitive bidding led the various departments of the government, the railroads and other large consumers, to issue specifications for rubber insulation. These specifications were based upon the individual experience or theories of a number of engineers, aided by suggestions from some of the manufacturers. For several years no attempt was made to standardize these specifications, and much trouble was given to the manufacturers by

Digitized by Google

the diversity of requirements contained in them. In 1906, the Rubber-Covered-Wire Engineers' Association, consisting of representatives of the leading manufacturers, prepared a specification which was offered as a standard. This was followed in 1911 by the revised specifications of the National Board of Fire Underwriters, which, however, call for a comparatively low grade of compound. The former specification, although the best that could be agreed upon at that date, was so defective as to afford little or no protection to consumers. The latter occupies a field by itself, and makes no pretension to specifying the highest quality of compound. Consumers desiring high grade insulation of great permanence, therefore, continued to use their own specifications, altering them from time to time, in accordance with the best information available, with a growing tendency to rely upon chemical rather than physical tests. Some difficulty was experienced both in obtaining bids and in enforcing these specifications owing to the inability of chemists to make concordant analyses of rubber compounds. This matter reached an acute stage in 1911, when a number of manufacturers and consumers held a conference in order to discuss the possibility of standardizing specifications and analytical methods for rubber insulation. This conference was held at New York on the seventh of December, 1911, Col. Samuel Reber of the U. S. Signal Corps presiding.* The following interests were represented:

Signal Corps, U. S. Army,
American Chemical Society,
Lederle Laboratories,
New York Central Lines,
Pennsylvania R. R. Co.,
General Electric Co.,
Hazard Manufacturing Co.,
Simplex Wire & Cable Co.,
Standard Underground Cable Co.

10. After a full discussion of the subject, a committee was appointed to devise a specification and an analytical procedure for rubber insulation, the committee to report at a future conference. The chairman, assisted by other members, appointed the following to serve upon this committee which was named "The Joint Rubber Insulation Committee."

C. R. Boggs, Simplex Wire & Cable Co.,
W. S. Clark, General Electric Company,
W. A. Del Mar, N. Y. C. R. R. Co., (later Interborough Rapid Transit Co.)
W. B. Geiser, N. Y. C. R. R. Co.,
J. P. Millwood, Consulting Chemist,
P. Poetschke, Lederle Laboratories,
H. B. Rodman, Pennsylvania R. R. Co.

Later, at the request of the committee and by unanimous consent of the members of the original conference, the following were added:

J. B. Tuttle, U. S. Bureau of Standards,
E. L. Willson, Hazard Manufacturing Company.

* The invitations were issued by Mr. E. B. Katte, Chief Engineer of Electric Traction, of the New York Central R. R. Co.

Digitized by Google

11. W. A. Del Mar was elected secretary of both the Conference Committee and of the Joint Rubber Insulation Committee. No permanent chairman was elected, it being left to the committee to elect a chairman at each meeting.

12. The committee immediately upon its formation decided to confine itself to the development of a specification and an analytical procedure for compounds of the 30 per cent Para type. In accordance with this policy it made a study of the chemical characteristics of Hevea rubber and of the available analytical procedures. New procedures were also developed and studied. Samples of different rubber compounds were analyzed by these tentative methods. The results were unsatisfactory and the discrepancies were investigated. Sub-committees were formed to do much of this work. Twelve regular committee meetings, besides numerous sub-committee meetings, were held; many different compounds were distributed to be analyzed by the entire committee, and others were experimented upon by the sub-committees and individual members.

13. After two years of this work the committee presented a preliminary report to a second conference which was held at New York on October 15th, 1913, Col. Reber again presiding. The report was unanimously accepted by the conference and the committee authorized to continue in existence for another year for the purpose of making any revisions that might appear necessary in its report, as the result of a year of experience with it.

14. The committee was also authorized to publish the preliminary report. This was accomplished through the courtesy of the American Chemical Society, the American Institute of Electrical Engineers, and the U. S. Bureau of Standards; the report appearing in their official publications, the Journal of Industrial and Engineering Chemistry, (January 1914), the Proceedings of the American Institute of Electrical Engineers, (January 1914), and Bureau of Standards Circular No. 38, respectively.

15. Instead of reporting in a year, the committee found it necessary to devote nearly three years to this work, holding 13 additional meetings, or a total of 25 general meetings exclusive of sub-committee meetings.

16. The committee was authorized, at the second conference, to increase its personnel without securing the approval of the Conference Committee. It has added the following chemists to its membership:

A. E. Ellis, Interborough Rapid Transit Co., New York,
G. d'Eustachio, Standard Underground Cable Co.,
E. W. Gundy, Pennsylvania R. R. Co.,
C. W. Walker, American Steel & Wire Co.,
C. F. Woods, A. D. Little Co., Inc., Boston.

17. The following resignations have been accepted since the second conference:

J. P. Millwood,
P. Poetschke.

Mr. Geiser also resigned, due to stress of other work, but has been re-elected.

18. The Joint Rubber Insulation Committee's specification for rubber insulating compound has been adopted by the principal engineering so-

Digitized by Google

cieties which issue standards of the kind. Among these are the American Electric Railway (Engineering) Association, the Association of Railway Electrical Engineers and the American Society for Testing Materials. The specification has also been adopted by a large number of important purchasers of insulated wire, including The U. S. Signal Corps, the Panama Canal, the New York Central R. R. Co., the Interborough Rapid Transit Co., the Public Service Corporation of New Jersey, etc.

19 The committee also desires to express its thanks to the many gentlemen not members, who have actively participated in the work, especially to Messrs. F. S. Deemer, F. A. Hull, M. M. Kahn, C. B. Martin, G. H. Savage, J. F. Tinsley and D. Whipple.

PART II—SPECIFICATION FOR 30 PER CENT HEVEA RUBBER COMPOUND (CHEMICAL CLAUSES)

1. A 30 per cent fine Para or best quality plantation Hevea rubber compound with mineral fillers, shall be furnished. It shall contain only the following ingredients:

Rubber,
Sulphur,
Inorganic mineral matter,
Refined solid paraffine or ceresine.

2. The vulcanized compound shall conform to the following requirements, when tested by the procedure of the Joint Rubber Insulation Committee, results being expressed as percentages by weight of the whole sample:

Requirements Independent of the Amount of Rubber Found

	Maximum	Minimum
Rubber	33	30
Waxy hydrocarbons	4	..
Free sulphur	0.7	..

Red lead, carbon, or organic fillers shall not be present.

Requirements Dependent Upon Amount of Rubber Found.

(Requirements for intermediate percentages shall be in proportion to the percentage of rubber found).

Limits allowed for 30 per cent Rubber Compound.	Maximum	Minimum
Saponifiable acetone extract	1.35	0.55
Unsaponifiable resins	0.45	....
Chloroform extract	0.90	....
Alcoholic potash extract	0.55	....
Total sulphur (see note 2)	2.10	....
Specific gravity	....	1.75
Limits allowed for 33 per cent Rubber Compound.		
Saponifiable acetone extract	1.50	0.60
Unsaponifiable resins	0.50	....
Chloroform extract	1.00	....
Alcoholic potash extract	0.60	....
Total sulphur (see note 2)	2.30	....
Specific gravity	....	1.67

Digitized by Google

3. The acetone solution shall not fluoresce.

4. The acetone extract (60 cu. cm.) shall be not darker than a light straw color.

5. Hydrocarbons shall be solid, waxy and not darker than a light brown.

6. Chloroform extract (60 cu. cm.) shall be not darker than a straw color.

7. Failure to meet any requirement of this specification will be considered sufficient cause for rejection.

8. Contamination of the compound, such as by the use of impregnated tapes, will not excuse the manufacturer from conforming to this specification.

Note: 1—This specification shall be supplemented by appropriate clauses relating to tensile strength, elasticity, electric insulation resistance and dielectric strength. (See the Wire and Cable specifications of the American Society for Testing Materials, the Association of Railway Electrical Engineers etc., for examples of such clauses.)

Note 2:—The limit on total sulphur may be omitted at the option of the purchaser. See Part IV, of Report.

Part III—Analytical Procedure

Object of the Analysis

1. The object of this procedure of analysis is to determine whether rubber compounds comply chemically with the accompanying specification which is intended to secure compounds containing 30 per cent of the best Hevea rubber, and mineral fillers.

Outline of Procedure

2. The general procedure is shown by the accompanying Diagram A.

General

3. Make the analysis upon the insulation after vulcanization and, whenever possible, before the saturation of the braid. Wipe the insulation thoroughly with a damp cloth to remove any adhering material, but do not remove waxy hydrocarbons from the surface.

4. If, however, a saturated braided sample must be used, remove the braid and sandpaper the insulation to a depth of at least 0.005 of an inch and wipe with a damp cloth. The latter procedure, however, is not to be recommended, as it may cause an appreciable error in the acetone extract. In such cases report the condition of the sample.

5. Perform all determinations in duplicate and take the average value arbitrarily as the true value. Duplicate determinations must check within the limits specified.

6. Make blanks on all determinations and deduct the results accordingly.

Sample

7. Remove the insulation entirely from sufficient wire to give a sample weighing about 25 grams. Cut this into small pieces* and grind slowly in either a No. 0 Enterprise coffee mill or a mill such as shown by the accompanying Diagram B. Adjust the grinder so that not more than 20 per cent will pass through a 40-mesh sieve. Sift all the material through a

* This is most conveniently done with a meat-chopper.

Digitized by Google

20-mesh sieve, regrinding what is retained on the sieve until the entire sample has passed through. The wires of the sieves shall be evenly spaced in both directions and shall be of 0.016 and 0.010 inches diameter in the 20-mesh and 40-mesh sieves respectively. Remove with a strong magnet any metal that may have come from the grinder and thoroughly mix the sample.

Extraction Apparatus

8. The extraction apparatus shall conform with the accompanying Diagram C. It shall be heated so that the period of filling an empty syphon cup with acetone and completely emptying it, will be between two and one-half and three and one-half minutes.

Preparation of Reagents

9. Acetone shall be freshly distilled over anhydrous potassium carbonate using the fraction 56-57 deg. cent.

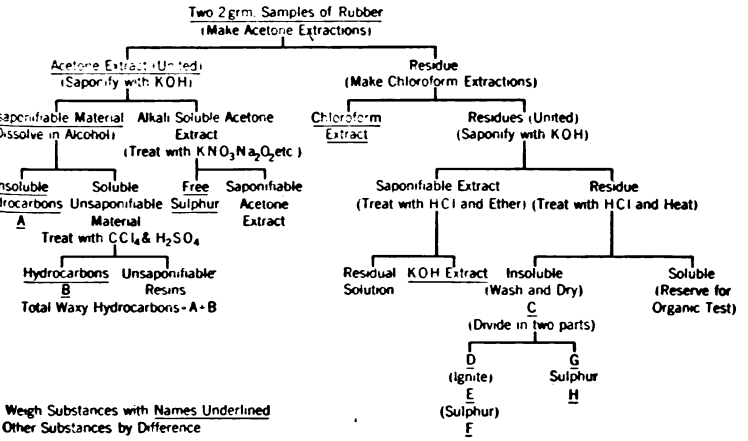


DIAGRAM A—OUTLINE OF METHOD OF RUBBER ANALYSIS EXCLUSIVE OF TOTAL SULPHUR DETERMINATION

10. Alcoholic potash solution shall be of normal strength and shall be made freshly by dissolving the proper amount of potassium hydrate (purified by alcohol), in 95 per cent alcohol which has previously been distilled over potassium hydrate. The solution shall be allowed to stand for 24 hours and only the clear liquid used.

11. Ether shall be washed with three successive portions of distilled water and distilled, using the fraction 34-36 deg. cent.

12. Chloroform shall be shaken with water, dried by calcium chloride, decanted, and freshly distilled, only the clear distillate being used.

13. Carbon tetrachloride shall be pure and freshly distilled.

14. The nitric acid bromine reagent shall be prepared by adding a considerable excess of bromine to the concentrated nitric acid shaking thoroughly and allowing it to stand for some hours before using.

15. The fusion mixture for sulphur determinations shall be made by

Digitized by Google

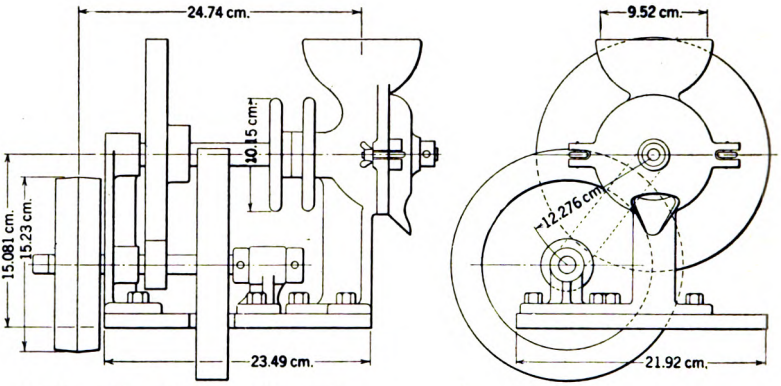
mixing equal quantities of sodium carbonate and powdered potassium nitrate.

16. The barium chloride solution shall be made by dissolving 100g. of crystallized barium chloride in one liter of distilled water and adding two or three drops of concentrated hydrochloric acid. If there is any insoluble matter or cloudiness, the solution shall be heated on a steam bath overnight and filtered through 589 S. and S. blue ribbon filter paper.

17. Distilled water only shall be used in preparing solutions and in all washing operations. Reagents not otherwise specified shall be of a "c.p. tested" quality.

Acetone Extract

18. Extract continuously with 60 cu. cm. acetone for eight hours, two 2-g. samples that have been prepared within 24 hours. Unite the extracts in a weighed flask, using hot chloroform to rinse the flasks. Distill off the reagents and dry the flask and contents for four hours at 95-100 deg.



Grinding plates of the No. 0 Enterprise Coffee Mill to be used

DIAGRAM B—RUBBER GRINDER

cent. Desiccate until cool and weigh. Continue to dry for two-hour periods until constant weight is obtained. In drying, place the flask on its side but at a sufficient angle from the horizontal so that the extract does not appreciably run down the side of the flask.

Unsaponifiable Material

19. Add to the acetone extract 50 cu. cm. alcoholic potash solution, boil under a reflux condenser for two hours, and evaporate on a water bath until all alcohol is removed. Add 10 cu. cm. water and 20 cu. cm. ether; heat until the wax etc. are in solution, cool, transfer to a separatory funnel, wash out the flask with warm water, cool and finally wash with two 20 cu. cm. portions of ether. The water volume should be 100 cu. cm. and the ether at least 40 cu. cm. Shake vigorously for two minutes, and allow the solutions to separate thoroughly. Draw off the aqueous solution into a second funnel, leaving in the first funnel the ethereal solution and any flocculent material that may be present. Again rinse the flask

Digitized by Google

with 20 cu. cm. ether and add it to the aqueous solution; shake vigorously for two minutes, and when separated draw off the aqueous solution and unite in the first funnel the ethereal solutions and any flocculent material. Repeat, shaking with 20 cu. cm. portions of ether, until no residue is obtained on evaporating a 20 cu. cm. portion. The aqueous solution and subsequent washings shall be reserved for the free sulphur determination. Wash the flask and the funnel, from which the ethereal solution has been taken, with water, until they are free from alkali. Wash the ethereal solution with water until it has been washed twice after the wash water shows no alkaline reaction. Retain with the ethereal solution any flocculent material. Filter the ethereal solution from the flocculent material,

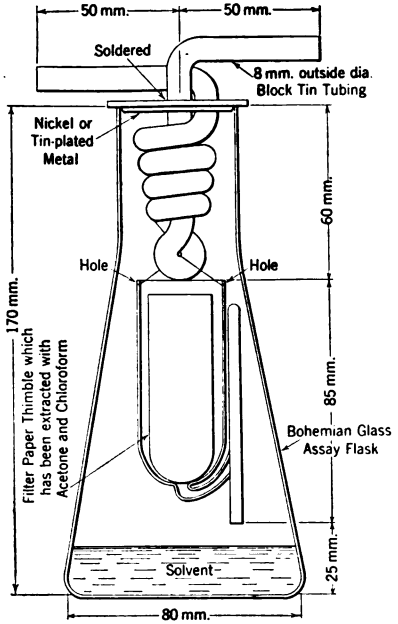


DIAGRAM C—RUBBER ANALYSIS EXTRACTION APPARATUS

through a small pellet of extracted cotton, into a weighed flask, washing first with ether and subsequently with hot chloroform, using this to rinse the original flask and both separatory funnels. Evaporate the solvents and dry the extract at 95-100 deg. cent.; cool in a desiccator and weigh. Continue to dry until constant weight is obtained.

Hydrocarbons A

20. Add 50 cu. cm. absolute alcohol to the unsaponifiable material and warm until solution is as complete as possible. Cool the solution to −4 or −5 deg. cent. and maintain at this temperature for one hour by packing the flask in a mixture of ice and salt. Filter out the waxy hydrocarbons, using a funnel packed with ice and salt, and apply suction if necessary. Wash the flask and filter with about 25 cu. cm. of 95 per cent alcohol,

Digitized by Google

which has been previously cooled in the same temperature. Catch the filtrate in a flask which is afterwards cooled to -4 to -5 deg. cent. to make sure that all possible waxy hydrocarbons have been removed, and refilter if necessary. Dissolve the residue on the filter paper with hot chloroform, into the original flask. Evaporate the chloroform and dry the flask at 95-100 deg. cent.; cool in a desiccator and weigh. Continue to dry until constant weight is obtained.

Hydrocarbons B

21. Evaporate the alcohol from the flask containing the alcohol-soluble unsaponifiable material, add 25 cu. cm. of carbon tetrachloride, and transfer to a separatory funnel. Shake with concentrated sulphuric acid, drain off the discolored acid and repeat with fresh portions of acid until there is no longer any discoloration. After drawing off all the acid, wash the carbon tetrachloride solution with repeated portions of water until all traces of acid are removed. Transfer the carbon tetrachloride solution to a weighed flask; evaporate off the solvent and dry the flask at 95-100 deg. cent.; cool in a desiccator and weigh. Continue to dry until constant weight is obtained.

Free Sulphur

22. Add two grams potassium nitrate to the aqueous solution and washings from the ethereal separation of the unsaponified material. Evaporate to dryness in a silver or nickel dish and heat to quiet fusion, avoiding contamination with sulphur fumes. Transfer with cold water to a beaker, neutralize with hydrochloric acid; add 2 cu. cm. concentrated hydrochloric acid; filter and wash, making a volume of 200 cu. cm. Heat to boiling and add slowly a slight excess of hot barium chloride solution. Allow to stand over night, filter, wash, ignite, weigh the barium sulphate and calculate to sulphur.

Definition of Terms Describing Components of Acetone Extract

23. The difference between the acetone extract and the free sulphur shall be called the Organic Extract.

24. The difference between the organic extract, and the unsaponifiable material shall be called the Saponifiable Acetone Extract.

25. The sum of the hydrocarbons A and B shall be called the total Waxy Hydrocarbons.

26. The difference between the unsaponifiable material and the waxy hydrocarbons shall be called Unsaponifiable Resins.

Chloroform Extract

27. Extract continuously, the residues from both of the acetone extractions (without necessarily removing the acetone that may be on them), for four hours with 60 cu. cm. chloroform. Unite the extractions in a weighed flask, using hot chloroform to rinse the flasks. Distill off the solvent and dry the flask and contents for two hours at 95-100 deg. cent. Cool in a desiccator and weigh. Continue to dry for one-hour periods until constant weight is obtained. In drying, place the flask on its side but at a sufficient angle from the horizontal so that the extract does not appreciably run down the side of the flask. (If it is needful to wait after the acetone extraction, before starting the chloroform extraction, the sample must be kept in a vacuum of at least 50 mm. of mercury.)

Digitized by Google

Alcoholic Potash Extract

28. Dry the residues from the chloroform extractions at 50-60 deg. cent. until the odor of chloroform can no longer be detected; unite the residues from the two 2 g. samples in a 200 cu. cm. Erlenmeyer flask. Add 100 cu. cm. alcoholic potash solution and boil for four hours under a reflux condenser. Filter the solution by decantation through an 11 cm. hardened filter paper into a beaker and wash twice, using each time 25 cu. cm. hot absolute alcohol and then wash thoroughly with hot water. Wash any rubber on the filter paper back into the original flask and reserve this for the determination of rubber hydrocarbons. Evaporate the solution to approximate dryness, take up in warm water and transfer to a separatory funnel. Acidify with 30 cu. cm. of 5 N hydrochloric acid, using this to rinse the beaker. Add sufficient water to make the bulk of the solution 100 cu. cm. When cool add 40 cu. cm. ether, using it to rinse the beaker in 20 cu. cm. portions. Shake the aqueous and ethereal solutions thoroughly. After complete separation, draw off the aqueous solution and treat in another separatory funnel, with a fresh 20 cu. cm. portion of ether. Continue to shake the aqueous solution with fresh portions of ether until a colorless portion has been obtained, then shake out twice more. Unite the ethereal solutions and wash with successive additions of water, continuing twice after the water shows no acid reaction. Filter through a plug of extracted cotton into a tarred flask, wash the filter and funnel with ether, evaporate the ether without boiling and dry the residue at 95-100 deg. cent.; cool in a desiccator and weigh. Continue to dry until constant weight is obtained.

Rubber Hydrocarbons

29. Add to the flask containing the rubber residue from the alcoholic potash extraction, sufficient water to make the total volume of the solution 125 cu. cm. and then add 25 cu. cm. concentrated hydrochloric acid. Heat for an hour at 97-100 deg. cent. Decant the supernatant liquid through a hardened filter paper on a Buchner funnel 7 cm. diameter, using suction; wash the residue with 25 cu. cm. hot water and decant. (While a Buchner funnel is recommended, it is permissible to use an 11 cm. hardened filter paper with platinum cone, in a 60 deg. funnel). Perform this entire treatment with water and hydrochloric acid, three times and save the first and second decantations for the "organic matter" test described in section 36. The rubber at this stage should be white and practically free from black specks of undissolved fillers; if not, continue the acid treatment until the black specks disappear. (If carbon is present, all the particles of rubber will be greyish, bluish, or black, depending on the form and quantity of carbon used. Black specks in light particles of rubber usually indicate the presence of lead sulphide which must be removed to prevent the formation of lead sulphate on igniting the residue *C*.) Add 150 cu. cm. hot water to the flask and let stand on a steam bath or hot plate for half an hour and decant through the filter paper. Return to the flask any rubber that goes on the filter paper. Repeat until the washings are free from chlorides. (See section 36). Transfer all the rubber in the flask to the filter paper and dry as much as possible by suction. Wash the rubber with 50 cu. cm. of 95 per cent alcohol, using suction. Transfer the entire residue to a

Digitized by Google

weighing bottle. Dry at 95 to 100 deg. cent. for an hour, cool in a vacuum dessicator under reduced pressure and weigh. Dry for a half hour, cool and weigh, repeating this process until either constant weight is reached or the weight starts to increase. Let this weight be represented by C. On a portion D of this residue C determine the ash E according to section 30 and the sulphur F in the ash E. Determine the sulphur H in another portion G of residue C. Make all sulphur determinations as described under Total Sulphur.

30. Place about 0.5 g. of residue C into a weighed porcelain crucible. Let the weight of residue be represented by D. Heat gently, gradually driving off the volatile matter. When the crucible has ceased to smoke, raise the temperature gradually to between 450 and 500 deg. cent. until all organic matter has been burned away, which is usually indicated by the ash becoming white. (An electric muffle furnace with pyrometer is recommended for this purpose). Cool in a desiccator and weigh, the weight of ash being represented by E in the formula for rubber hydrocarbons. Make sulphur test on ash by the method described under Total Sulphur. If, however, $50 \times C \times E$ is not over unity, the determination of sulphur in the ash may be omitted and F assumed to be zero.

Then,

$$\text{Rubber Hydrocarbons} = \frac{100\ C}{4}\left[1 - \frac{E-F}{D} - \frac{H}{G}\right]$$

expressed as a percentage of the total sample.

Total Sulphur

31. Place a 0.5g of rubber in a porcelain crucible of about 100 cu. cm. capacity. Add 20 cu. cm. nitric-acid-bromine reagent, cover the crucible with a watch glass, and allow to stand for one hour. Heat very carefully for an hour, remove the cover, rinsing it with a little water, and evaporate to dryness. Add 5g. of the $KNO_3 - Na_2CO_3$ fusion mixture, and 3 to 4 cu. cm. of distilled water. Digest for a few minutes, and then spread the mixture half way up the side of the crucible to facilitate drying. Dry on a steam bath or hot plate. Fuse the mixture, using a sulphur-free flame until all the organic matter has been destroyed and the melt is quite soft. Allow to cool, place the crucible in a 600 cu. cm. beaker, and cover with water. Digest three or four hours on the steam bath. Filter into an 800 cu. cm. beaker, washing thoroughly with hot water. The total volume should be about 500 cu. cm. Allow to cool, add 7 to 8 cu. cm. concentrated hydrochloric acid to the filtrate, and heat on the steam bath. Test the solution for acidity with congo paper and add 10 cu. cm. of hot barium chloride solution. Allow to stand over night, filter, wash, weigh the barium sulphate, and calculate to sulphur.

Specific Gravity

32. The specific gravity shall be the ratio of the weight of a given volume of the compound, to the weight of an equal volume of water; both at 20 deg. cent. Cut strips of the largest practicable size from the conductor and use about 5 g. for the sample. Determine the specific gravity in the usual manner by means of a specific-gravity bottle. Care must be taken that no air bubbles adhere to the sample.

Digitized by Google

Checks

33. Specific gravity determinations shall check within 0.01. The other duplicate determinations shall check within the following limits expressed as percentages of the original sample.

Determination	Check
Acetone Extract	0.10
Saponifiable Acetone Extract	0.10
Unsaponifiable Resins	0.10
Waxy Hydrocarbons	0.10
Free Sulphur	0.05
Chloroform Extract	0.10
Alcoholic Potash Extract	0.10
Rubber Hydrocarbons	0.20
Total Sulphur	0.10

Interpretation

34. The percentage of rubber shall be considered to be the sum of the rubber hydrocarbons, saponifiable acetone extract, unsaponifiable resins, chloroform and alcoholic potash extracts, expressed as percentages. If the chloroform extract is over 3.0 per cent of the rubber so calculated, subtract the excess from the rubber. If the alcoholic potash extract is over 1.8 per cent of the rubber, as first calculated, subtract this excess also from the rubber.

Red Lead

35. Dissolve 1 g. of the sample in 75 cu. cm. Xylol at a temperature of about 100 deg. cent. When the rubber is dissolved, the absence of any red particles indicates the absence of red lead. If red particles are present, filter the solution into a Gooch crucible and wash thoroughly with benzol, acetone and alcohol successively. Remove the felt and residue to a distilling flask, add 25 cu. cm. 10 per cent hydrochloric acid, and distill over the chlorine liberated by the lead peroxide, absorbing the gas in a solution of potassium iodide and starch. Not more than 0.1 cu. cm. of 0.1 N thiosulphate shall be required to titrate the iodine liberated.

Organic Fillers.

36. Transfer the first and second decantations of the hydrochloric acid solutions to a carefully cleaned porcelain dish and add 20 cu. cm. concentrated sulphuric acid. Place dish on steam bath or hot plate to drive off water and hydrochloric acid. A pronounced charring of the residue indicates the presence of organic matter soluble in water or hydrolyzed by hydrochloric acid.

Examine filter paper and rubber while decanting acid solution and again while washing free of chlorides. Some types of organic fillers not removed by water and hydrochloric acid, would be plainly visible at this point.

Place a small portion of residue *C* under a microscope and examine for fibrous and other characteristic organic material. If organic fillers are indicated and not clearly proven by this test, place 1 g. of the organic sample in a beaker, add 75 cu. cm. Xylol and heat on hot plate until the rubber is dissolved. Decant Xylol solution and wash residue with ether

Digitized by Google

several times by decantation. Dry residue and examine under the microscope.

Statement of Results

37. The results of the analysis shall be stated in the following form:

	per cent
Acetone extract	
Saponifiable acetone extract	
Unsaponifiable resins	
Waxy hydrocarbons	
Free sulphur	
Chloroform extract	
Alcoholic potash extract	
Total sulphur	
Rubber	
Color of acetone extract (60 cu. cm. vol.)	
Fluorescence in acetone extract solution (present or absent)	
Hydrocarbons *A* (consistency and color)	
Hydrocarbons *B* (solid or liquid)	
Color of chloroform extract (60 cu. cm. vol.)	
Carbon (present or absent)	
Organic fillers (present or absent)	
Red lead (present or absent)	
Specific gravity	
Sample braided or not	

PART IV—EXPLANATION OF SPECIFICATION

1. Experience has shown that compounds of the grade which contains only good Hevea rubber, may be relied upon to be more permanent than those made of rubber of other grades. It is not affirmed by the committee that a compound which conforms with this specification, is necessarily permanent, or that a better compound cannot be made, but it is believed that enforcement of the specification will limit the use of inferior materials and that it will put the manufacturers more nearly upon an equality of endeavor, where they can use their experience to obtain the best results. Used in connection with the analytical procedure, the specification will enable purchasers to order a good compound and to ascertain with a greater certainty than heretofore, whether the material received, represents the compound specified.

2. The term Hevea applied to rubber means rubber from the Hevea Brasiliensis tree whether wild or cultivated and regardless of the locality in which it has been grown. Para rubber is Hevea rubber of the kind originally shipped from the port of Para, Brazil, and comes in several grades. The rubber required by this specification should be Hevea rubber of good quality, such as fine Para or best quality plantation rubber.

3. Carbon is excluded not only because it is considered, by some purchasers, to be deleterious, but because it interferes with the determination of rubber hydrocarbons.

4. Red lead is excluded because of the possibilities of its deleterious effects on the rubber.

Digitized by Google

5. Ozokerite is prohibited because the acetone extract obtainable from it interferes with the separation of the acetone extract obtainable from the rubber, thereby vitiating the assay of the rubber extract. This prohibition is unimportant to the manufacturers, as ceresine, which is permitted, is the essential constituent of ozokerite.

6. An upper limit is placed upon the rubber in order to prevent the attainment of electrical and mechanical strength by the use of an extra quantity of inferior rubber whose lasting qualities might not be satisfactory.

7. The hydrocarbons are limited owing to their tendency to separate from the compound and thus possibly cause porosity.

8. The free sulphur is limited because an excessive amount may be deleterious.

9. The maximum limit on the saponifiable acetone extract is to prevent the use of raw or reclaimed rubber with high saponifiable extract. The minimum limit assists in forcing the use of Hevea rubber, since it is characteristic of the acetone extract from Hevea rubber to be largely saponifiable.

10. The unsaponifiable resins are limited because a low proportion of unsaponifiable resins is characteristic of Hevea rubber. A high result might be due to the presence of reclaimed rubber.

11. The chloroform extract is limited, first to prevent the use of bituminous substances, and second, to limit depolymerized and undercured rubber.

12. The alcoholic potash extract is limited to prevent the use of saponifiable rubber substitutes.

13. The specific gravity is limited to reconcile the specification of ingredients by weight with the practise of purchasing material by volume.

14. Fluorescence of the acetone solution is prohibited as it indicates the presence of bituminous substances, rosin oil, or mineral oils.

15. The color of the acetone extracts is specified to conform with the normal color of the extract from Hevea rubber. A darker color indicates adulteration or an inferior grade of rubber.

16. The hydrocarbons are required to be solid in order to prevent the use of oils and paraffine of low melting point. The shade required is that obtained from paraffine wax or ceresine. If hydrocarbons *B* are liquid this would indicate reclaimed rubber softened with mineral oil, or paraffine of low melting point.

17. The color of the chloroform extract is specified to conform with the color of dissolved gum in minute quantities. The presence of bituminous substances would be indicated by a brown or black color.

18. It would be desirable that the sulphur of vulcanization be limited to exclude reclaimed rubber, which contains the sulphur of its previous vulcanization, but the committee has not yet developed an acceptable method for determining this quantity. It is, therefore, confronted with the choice of either placing a limit on the total sulphur or giving up the attempt to exclude shoddy by sulphur limitation. Option is therefore given to the purchaser to insert or omit the limit on total sulphur. Such insertion will at times exclude reclaimed rubber and the committee believes it possible to make a suitable compound with this limitation. The com-

Digitized by Google

mittee thinks that a sulphur limit positively excluding reclaimed rubber, would place too great a hardship, in other ways, on the manufacturers. Where the specification is used with no total sulphur limit, the use of many kinds of, or much, reclaimed rubber, will be guarded against by the limits of the various components of the acetone extract. When the limitation on total sulphur is omitted, sulphur-bearing fillers, which possess certain advantages, may be used.

19. This specification should be supplemented by appropriate elasticity and tensile strength tests, in order to add to the assurance that good rubber has been used and that the vulcanization process has been properly carried out; also by appropriate electric stress and resistance tests, to assure proper insulating qualities and homogeneity of structure. The exact value of the limits for these tests will depend upon the use to which the material is to be put.

PART V—EXPLANATION OF PROCEDURE

General

1. The tentative report of the committee, presented in October, 1913, provided for the determination of the percentage of rubber present by the method of difference. The mineral fillers were determined by the terebene solution method. Results obtained in the use of this method showed that it gave inaccurate results on some compounds. The committee therefore determined to abandon it and to find a suitable substitute. It is believed that the method now recommended will satisfactorily solve the problem.

2. The most feasible means of limiting the kind of rubber was considered to be the determination of the saponifiable and unsaponifiable resins. These are fairly constant characteristics of the resins of Hevea rubber, and of compounds made from the same. Other methods, such as the determination of the saponification number and the optical activity of the resins, were thought to be unpractical.

3. The method as developed is applicable to the analysis of any pure rubber compound containing only mineral matter with or without ceresine or paraffine wax, regardless of the kind or amount of rubber, and can be used in conjunction with other specifications provided the limits are changed to correspond with the amount and kind of rubber desired, and due consideration is given to interfering mineral matter. When applied to a compound without ceresine or paraffine wax the unsaponifiable acetone extract is the unsaponifiable resins.

4. The method has been definitely described, to make it certain that experienced chemists may obtain concordant results. The interpretation has been rigidly defined, obviating any ambiguity as to the meaning that will be assumed, even though this sometimes appears to be arbitrary.

Sample

5. In order to obtain uniform results, the committee has established by experiment that a definite method of sampling has to be adopted and that for all extractions the sample must be reduced in a prescribed manner to at least an approximately similar degree of fineness. For this reason the procedure specifies a definite type of grinder obtainable in two forms, and also specifies definite sieves.

Digitized by Google

Extraction Apparatus

6. The committee has proved that the extraction apparatus used by different chemists must be of exactly the same form and the same size. It was also proven that small samples in the apparatus give the maximum results and that the rate of extraction is dependent upon the amount of solvent and its temperature as it passes through the sample. The apparatus finally adopted combines the advantages of several forms that were studied and together with simplicity of operation and adjustment to uniform conditions, gives practically complete extraction when used as specified. A number of other variations that might have a possible effect upon the amount of extract, were tried but found to be inappreciable.

Acetone Extraction

7. The extraction is made within 24 hours of the preparation of the sample, so obviating any appreciable oxidation. Two samples are extracted and united, so that a larger amount of extract may be obtained for the subsequent separations, and the extraction apparatus kept within a convenient size. Hot chloroform is used to facilitate the complete transference of the extract. The flasks are placed on their sides when drying, to hasten the emission of the solvent and thus reduce chance of volatilizing, through longer heating, some of the more volatile constituents of the extract. Drying in vacuo at room temperature, does not remove all the moisture if paraffine is present and such drying with heat or at 100 deg. cent. in an inert gas, presents no practical advantage over the method given.

Separation of the Acetone Extract

8. The method given was developed so that all the desired constituents could be determined on one sample.

9. Emphasis is laid on thorough extraction of the unsaponifiable material and the retention of the flocculent material with the ethereal solution. This latter material is not soluble in either ether or water, but it was proven that if such as was chloroform-soluble was included in the unsaponifiable material, the subsequent determination of the hydrocarbons would be more exact. A portion of this flocculent material is insoluble in chloroform.

10. The hydrocarbons are determined in two places, making an approximate separation between the solid and the liquid ones, if both are present. The first hydrocarbons *A* are those insoluble in the solvent at a low temperature. The presence of unsaponifiable resins in the solution prevents the more complete freezing out of the hydrocarbons, but the remainder is obtained after treatment of the resins with sulphuric acid. In this way, chance of loss through the action of the acid has been largely eliminated.

11. The method for free sulphur gives all the sulphur in the acetone extract with the exception of negligible amounts which may be in the unsaponifiable material. It was proven that the results agree with determinations made directly on other acetone extracts.

12. The saponifiable and unsaponifiable resins are obtained by difference.

Digitized by Google

Chloroform Extraction

13. The chloroform extraction should be made at once after the acetone extraction, or the sample put in a vacuum, so as to avoid the danger of an abnormally high extract. When the extract is dried as specified, constant weight is obtained before any appreciable oxidation occurs. If bituminous substances are present, that portion which has not been extracted by the acetone, will be largely soluble in chloroform and can be readily distinguished by its color. The amount of extract is also affected by the presence of uncured and inferior rubber. A properly cured Hevea compound will always give a little extract with chloroform, which varies somewhat with the method and conditions of cure.

Alcoholic Potash Extraction

14. The alcoholic potash extraction is the usual saponification process for obtaining the fatty acids of rubber substitutes. The total amount of such substitutes is not obtained, but if any appreciable amount is present, the value will exceed that of the limit allowed. When no substitutes are present, this determination always yields a small amount of extract from Hevea rubber.

Rubber Hydrocarbons

15. Methods for the determination of the percentage of rubber are of two kinds, the direct and the difference methods. The committee adopted a difference method after trial of various methods, both direct and indirect.

16. The difference methods are those in which the rubber is removed and the residue weighed. This may be done in either of two ways; by the use of solvents, or by ignition. The early work of the committee was largely along the line of removing the rubber by means of solvents. Many kinds and probably every class of rubber solvents were tried. Some did not completely dissolve the rubber at low temperatures and ordinary atmospheric pressure; others appeared to dissolve the rubber, but formed a colloidal solution holding some of the fillers, which could neither be filtered nor centrifuged clear of mineral matter. Many of them were so time-consuming as to render them worthless, even if accurate results could be obtained. The solvent method given in the Preliminary Report was found to give inaccurate results with compounds containing much litharge or zinc oxide, but gave very good results on most classes of compounds if xylol, instead of terebene is used as the solvent. It has since been demonstrated, however, that it is practically impossible to obtain correct results on an important class of compounds and that method was, therefore, abandoned.

17. Ashing the compound gives fairly accurate results provided no volatile or decomposable fillers are included. This, however, cannot be assumed to be the case. In the method which the committee recommends, these objectionable fillers are largely removed before the compound is ignited, and provision is made for testing those few materials which are volatile, but not removed. This method is a modification of an unpublished one devised, some years ago, by G. H. Savage.

18. In the testing of this method, compounds containing most of the known commercial inorganic fillers were analyzed. Whiting, talc, magnesium, and lead compounds and barium carbonate which are objection-

Digitized by Google

able in direct ashing do not in any way interfere with the determination of rubber by this method. A number of organic fillers were used, but these too, did not cause any great error.

19. The securing of accurate results by the method given depends largely on two things; the complete solution of decomposable fillers, and the removal of all chlorides. With these precautions, the analyst is almost certain to obtain reasonably accurate results. The formula for calculating the rubber hydrocarbons presents no difficulty if the exact quantities called for in the method are used.

20. The rubber as it is weighed under *C* contains sulphur in combination with the rubber. On ignition sulphur is driven off with the rubber. By determining the sulphur before and after ignition, the amount so lost can readily be calculated, and the proper correction made.

Total Sulphur

21. The sodium peroxide method, specified in the Committee's Preliminary Report, is widely used in the analysis of wire insulation, and is known to yield accurate results on such compounds. The liability of explosion with that method, however, renders it somewhat objectionable.

It will be noted that the bromine-nitric-acid method which is now specified does not require the dehydration and separation of silica. If the filtrate after the fusion and extraction with water, is acidified in the cold, and after the precipitation of the barium sulphate the solution is not permitted to concentrate to a relatively small volume, any silica which is in solution will remain dissolved. The elimination of this step by proper precautions saves considerable time without in any way interfering with the accuracy of the determination.

Interpretation of Results

22. Emphasis is laid on the method of calculating the results. The saponifiable acetone extract and the unsaponifiable resins are considered to be parts of the rubber. The chloroform and alcoholic potash extracts, when within the limits specified, are also so considered. Any quantity in excess of these limits is assumed to be due to foreign substances or in case of chloroform extract, to undervulcanized rubber. No allowance is made for the ash in the raw rubber, as it is considered to be negligible. This method of calculation has to be adopted if the rubber found is to agree with that originally put into the compound.

Moisture

23. A determination of moisture is not given, as electrical tests will detect its presence if in excess. If electrical tests are required, the error introduced by the omission of this determination is very small.

Note:—With a procedure of this length it is impossible to explain every detail without undue elaboration, and the committee wishes to point out that while to experienced chemists the procedure may seem over burdened by detail, yet every specified detail was found necessary in order that the conditions essential to accurate and consistent work might be reproduced by all chemists using the procedure. For this reason it is extremely important that all instructions be observed, even if their significance is not perceived by the individual chemist. It will probably be found that even with the instructions properly observed, some experience will be needed to apply the method successfully.

Digitized by Google

PART VI—LIST OF IMPORTANT SPECIFICATIONS CONTAINING THE JOINT RUBBER INSULATION COMMITTEE'S CHEMICAL CLAUSES OR ANALYTICAL PROCEDURE

American Electric Railway (Engineering) Association:
Standard Specification for Rubber Insulated Wire and Cable.

American Society for Testing Materials:
Proposed Specifications for Insulated Wire and Cable; 30-per cent Hevea Rubber.

Association of Railway Electrical Engineers:
Standard Specifications for Wire and Cable.

Interborough Rapid Transit Co., Motive Power Department, New York:
Specification No. 2.

New York Central Railroad Co. Electrical Department:
Specification No. 300.

Panama Canal:
Office of General Purchasing Agent, Circular No. 1038.

Signal Corps, U. S. Army:
General Specification No. 581—A., etc.

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

EXPANSION EFFECTS AS A CAUSE OF DETERIORATION IN SUSPENSION TYPE INSULATORS

BY J. A. BRUNDIGE

ABSTRACT OF PAPER

In seeking causes for the rapid deterioration which has been encountered in suspension type insulators, two leading hypotheses, viz., porosity and mechanical cracking through expansion effects, have been advanced by different groups of investigators. These are briefly outlined in the paper, after which the author presents data in support of the latter. Some of the operating problems attendant upon insulator deterioration are also discussed.

INTRODUCTION

THE CONTINUED and seriously high rate of deterioration occurring in all parts of the country in high-voltage suspension insulators of the cap and stud type, has caused investigators in their efforts towards the design of a durable insulator, to make a more careful study of the problem than heretofore, for the purpose of trying to fix the underlying causes of failure. Had the problem been a simple one, it would doubtless have been solved before now, and in view of the number of factors involved, especially from the manufacturing standpoint, it is not only natural, but in fact a favorable sign of active and thorough investigation, that somewhat different views may at first be held as to the predominating causes of insulator deterioration by those engaged in making such studies.

As a result a number of engineers, together with a majority of those concerned in insulator manufacture, while recognizing that porosity undoubtedly has been responsible for a considerable percentage of failures, hold that mechanical cracking of the porcelain, brought about by expansion effects (possibly assisted by heavy cable loads) is the principal cause for the trouble experienced. This hypothesis is equivalent to saying that unless the more recent designs and methods of assembling have sufficiently reduced the mechanical stresses set up inside the cap, troubles with this type of insulator may be expected to continue,

Manuscript of this paper was received March 31, 1917.

Digitized by Google

regardless of the degree of perfection and freedom from porosity attained in the manufacture of the porcelain shells.

On the other hand, there are prominent investigators who have quite definitely taken the stand that practically all insulator deterioration is ultimately attributable to porosity, which either makes the porcelain weak electrically after moisture has been absorbed, or causes cracking through the capillary absorption and crystallization of salts taken up from the adjacent cement used in assembling, or causes a combination of both. The porosity hypothesis is in part based upon the results of experiments made with apparatus designed to measure extremely high resistances. With such apparatus, it has been shown that all porcelain is more or less conducting and that quite wide resistance differences exist between various specimens. A considerable variation in the resistance of certain specimens when subjected to treatment for the purpose of altering their moisture content has been also noted. These results, which are not surprising when considered in the light of the extreme sensitiveness of the instruments used and of the well known difficulty of producing well vitrified porcelain, have led some of these investigators to believe that all porcelain is inherently porous to such an extent as to make it unsuitable for manufacturing satisfactorily durable insulators.

The engineers of the company with which the author is associated in investigating the problem from an operating standpoint so far as somewhat limited facilities have permitted, and while having no desire to minimize the importance of porosity effects, have arrived at the belief that expansion effects are causing the major part of insulator deterioration, and the following notes and comments are given in support of this view. It is appreciated that many of the facts mentioned have only circumstantial value, but when considered together it will be evident that this belief is not without foundation.

General

Statement of Conditions Inside of Cap. Before referring to observed results, it is instructive to review the conditions existing inside the cemented metal cap of a suspension insulator.

It is well known that Portland cement after setting does not attain its ultimate hardness for a considerable period—usually months—but when this state is finally reached, it will withstand and transmit fairly large compressive stresses. Under these

Digitized by Google

conditions, the porcelain inside an insulator cap is directly subjected to varying forces which it is poorly adapted to withstand. The temperature expansion coefficient of porcelain being only approximately one-half that of steel, it is perceivable that from this source alone stresses amply sufficient to cause damage must occur as the result of seasonal temperature changes. Expansion in the steel stud on hot days is doubtless responsible for much of the trouble.

But another and even more serious form of expansion takes place inside insulator caps where Portland cement has been used for assembling, the existence of which has not been generally recognized. This is the expansion and contraction of the cement itself that the influence of varying moisture conditions. Mr. A. H. White* in a series of experiments extending for a period of nearly five years, on both old and new samples of concrete and cement obtained from various sources, has shown that from a dry to a completely moistened state, neat cement briquettes will expand as much as 0.15 per cent, which is equivalent to a temperature expansion change in cement of nearly 270 deg. fahr. (150 deg. cent.). In addition, it was shown that the effect was gradually progressive, the samples exhibiting a slight increase in length with each cyclic change. Other investigators have also noted this behavior of Portland cement, the generally accepted explanation of which is that it exhibits reversible collodial characteristics to a limited extent, analogous to the softening and swelling up of glue in the presence of water. The progressive expansion taking place with the cyclic changes is attributed to the incomplete hydration of some of the particles of cement, which are initially sealed up and protected, but as the expansion and contraction goes on, more of these are exposed to moisture so that additional setting takes place, accompanied by a certain amount of permanent expansion. This expansion was clearly indicated in the experiments mentioned by the numerous hair cracks which generally developed throughout the mass of the sample briquettes.

It is believed by the author that the much greater deterioration which has been experienced with insulators hanging in the tension or horizontal position as compared with that occurring in those suspended vertically, may be accounted for by the fact that the cement in the former is much more directly exposed to the elements, thus affording greater opportunity for the taking

*Proceedings Am. Society for Testing Materials, Vol. XIV, Part II, 1914, p. 204.

Digitized by Google

up of water and the reverse, whereas the cement in units in the upright position is not subjected to such marked extremes; also because of the greater relative exposure of the horizontally placed units to the hot sun, resulting in their undergoing more abrupt temperature changes. The great difference in the rate of deterioration observed in the two positions cannot be wholly accounted for by the fact that the tension insulators usually support heavier mechanical loads. While it is believed that excessive loads accelerate deterioration, several instances have been encountered where tension insulators carrying loads less than those on adjacent suspension insulators have shown percentage failures from 2 to 3 times as great and equalling the failures observed in tension insulators generally elsewhere on the same systems.

Data and Observations

The following notes relate to data from megger and oscillator tests made during the last three years on transmission systems located in widely separated parts of the country embracing an aggregate of over six hundred thousand suspension insulator units. It may be added that in drawing conclusions from the megger tests, care has been taken to select only readings made under favorable conditions and by testers experienced in handling the instrument, who were cognizant of its limitations and of the precautions to be observed in its use.

Electrical Stresses Not a Necessary Factor in Deterioration. Owing to the greater electrical stresses to which the end units of insulator strings are theoretically subjected, it might be expected that these would fail in comparatively greater numbers if such electrical stresses were a material factor. With one exception, the data on which have not been fully confirmed, no evidence has come to the notice of the author that the end units do fail at a greater rate. The following record from oscillator tests made on strain insulators units from a 60-kv. line in 1916 may be taken as typical. Potential was applied at 100 kv. for 5 seconds:

Unit No.	Location of defective units in string (No. 1 unit next to conductor)			Total defective
	Wire A	Wire B	Wire C	
1	40	35	34	109
2	40	33	39	112
3	37	37	39	113
4	42	42	30	114
5	40	38	30	108

Digitized by Google

Another phenomenon of much more conclusive nature showing that deterioration takes place independently of electrical stresses is the loss often observed in insulators where they have been left for some time in the original crates. In one instance reported from the Pacific coast, it was found that the percentage deterioration in a lot of several hundred units left over from line construction amounted to practically the same as that occurring in the ones in service. The crates containing the excess insulators were of the usual open type and had been stored in a yard for a period of approximately four years. Tests were made by means of the megger and the loss totaled nearly 5 per cent.

Insulator Failures are Not Proportional to Degree of Firing in Kiln. Referring to a lot of 877 units subjected to oscillator tests in 1915, and which represented the entire commercial range of firing, it was found that failures did not occur any more frequently in underfired shells than among the others. In fact, the overfired shells were the ones which showed a tendency to fail in excess of the average. This would indicate that the failures observed were influenced more by mechanical strength of the porcelain than by the degree of porosity. The degree of firing was only roughly estimated by classification of the glaze colors. but the results shown in the following table taken in conjunction with like data from other sources are believed to be sufficiently definite to justify the above conclusion.

	Total number	Bad	Per cent bad
Black Green	176	37	21.0
Green black	30	7	23.4
Greenish brown	12	4	33.3
Black	191	48	25.1
Dark brown (normal)	210	40	19.1
Brown	231	35	15.2
Light brown	27	6	22.2
	877	177	20.2per cent

In the above, dark brown is considered to represent normal firing, the brown and light brown underfired, while the black, greenish brown, green black and black green were overfired, the last exhibiting blebs.

A more striking instance is the failure on a certain system of a large number of foreign insulators, the porcelain of which

Digitized by Google

was exceptionally well fired and uniform in character. Although excellent service was afforded for the first three years, trouble afterwards became very serious and it is reported that practically all of these insulators have now been removed from the lines, after approximately six years operation. In this case, it has been fairly well established that the deterioration was due to cracking which was accentuated by a very unfavorable design of the head, including long embedded studs. Other insulators of American manufacture of a similar design have likewise failed on the same system in quite large numbers. It is interesting to note that the insulators of this design were prone to develop operating troubles on particularly hot days.

Rate of Deterioration. In testing with the megger it has been found that the great majority of the units read zero or nearly so when first discovered. The few units which did not read zero at first have, so far as observed, since changed in resistance but slightly and such of them as the author has examined show unmistakable evidences of porosity.

The rapidity with which deterioration takes place in insulator units is in many cases quite remarkable. On a certain high-voltage line, it is reported that insulators sometimes fall in resistance from infinity reading on a 2000-megohm megger to apparent zero during the course of a few days. An example is cited of an anchor tower carrying 120 units which had been gone over with the megger for removal of defective insulators. Four days later, the testing crew took occasion as a matter of interest, to remegger the insulators on the tower and were quite surprised to find that five more units had failed in the meantime. It is not stated whether any rains had occurred during the interval, but the weather had been quite hot.

That insulators suddenly fall in resistance from infinity reading on a megger to practically zero is believed to be indicative of cracks rather than of porosity. The absorption of moisture in a piece of porous ware is known to be slow process and there are no grounds for suspecting that at a certain critical point of saturation the resistance drops so quickly as has been found.

Porosity in Small Amounts not Believed to be Excessively Harmful. The theory which has been advanced that conducting areas are formed by moisture within the body is undoubtedly valid for those cases where the porosity is marked, but the author believes that the performance of the numerous pin-type insulators which have been in use for comparatively long periods

Digitized by Google

and also of the Hewlett type units, some of which have been giving good service for approximately 10 years, shows quite conclusively that reasonably small amounts of porosity are not necessarily injurious. All of these older insulators are unquestionably of greater porosity than many of the suspension type manufactured comparatively recently and which have failed to a serious extent. It is true that pin-type insulators with cemented shells have failed in large numbers after considerable periods in service, but the cause can usually be traced to cracking from purely mechanical sources. An illustration is found on a 60-kv. southern line where the insulators, which were of the 4-part pin-type, operated perfectly for ten years, after which over 25 per cent failed during one summer. Without exception these insulators were found to have cracks in the upper shell generally following the side tie wire groove and sometimes extending radially out to the edge of the petticoat.

It has been determined by Prof. Creighton that where a porous insulator has become saturated with moisture, it is easily punctured by application of potential at ordinary frequencies. This fact led to the suggestion by others that insulators only slightly porous, after having been in service for several years so as to absorb moisture, might be discovered and weeded out before reaching a dangerous condition by subjecting them to a 60-cycle test at near flash-over voltage in order to line up the particles of moisture to form a conducting path, similarly to the lining up of particles of foreign matter between the electrodes in an oil testing set. Experiments were undertaken by a transmission company to apply this hypothesis, but the results obtained were negative in character so far as concerned substantiating the presence of porous ware. Such breakdowns as did occur could nearly always be traced to manufacturing defects in the porcelain.

Indications of Cracking. While the author has not had opportunity for the careful examination of any large number of faulty insulator units by the removal of the metal caps, such work has been done has afforded fairly consistent results. In order to remove the caps without disturbing the porcelain, a helical cut of suitable pitch is taken with a hack saw, beginning at the lower edge, which enables the metal at the side of the cap to be removed in the form of a strip, thus freeing the upper portion.

With the caps taken off it is still by no means an easy matter

Digitized by Google

was exceptionally well fired and uniform in character. Although excellent service was afforded for the first three years, trouble afterwards became very serious and it is reported that practically all of these insulators have now been removed from the lines, after approximately six years operation. In this case, it has been fairly well established that the deterioration was due to cracking which was accentuated by a very unfavorable design of the head, including long embedded studs. Other insulators of American manufacture of a similar design have likewise failed on the same system in quite large numbers. It is interesting to note that the insulators of this design were prone to develop operating troubles on particularly hot days.

Rate of Deterioration. In testing with the megger it has been found that the great majority of the units read zero or nearly so when first discovered. The few units which did not read zero at first have, so far as observed, since changed in resistance but slightly and such of them as the author has examined show unmistakable evidences of porosity.

The rapidity with which deterioration takes place in insulator units is in many cases quite remarkable. On a certain high-voltage line, it is reported that insulators sometimes fall in resistance from infinity reading on a 2000-megohm megger to apparent zero during the course of a few days. An example is cited of an anchor tower carrying 120 units which had been gone over with the megger for removal of defective insulators. Four days later, the testing crew took occasion as a matter of interest, to remegger the insulators on the tower and were quite surprised to find that five more units had failed in the meantime. It is not stated whether any rains had occurred during the interval, but the weather had been quite hot.

That insulators suddenly fall in resistance from infinity reading on a megger to practically zero is believed to be indicative of cracks rather than of porosity. The absorption of moisture in a piece of porous ware is known to be slow process and there are no grounds for suspecting that at a certain critical point of saturation the resistance drops so quickly as has been found.

Porosity in Small Amounts not Believed to be Excessively Harmful. The theory which has been advanced that conducting areas are formed by moisture within the body is undoubtedly valid for those cases where the porosity is marked, but the author believes that the performance of the numerous pin-type insulators which have been in use for comparatively long periods

Digitized by Google

and also of the Hewlett type units, some of which have been giving good service for approximately 10 years, shows quite conclusively that reasonably small amounts of porosity are not necessarily injurious. All of these older insulators are unquestionably of greater porosity than many of the suspension type manufactured comparatively recently and which have failed to a serious extent. It is true that pin-type insulators with cemented shells have failed in large numbers after considerable periods in service, but the cause can usually be traced to cracking from purely mechanical sources. An illustration is found on a 60-kv. southern line where the insulators, which were of the 4-part pin-type, operated perfectly for ten years, after which over 25 per cent failed during one summer. Without exception these insulators were found to have cracks in the upper shell generally following the side tie wire groove and sometimes extending radially out to the edge of the petticoat.

It has been determined by Prof. Creighton that where a porous insulator has become saturated with moisture, it is easily punctured by application of potential at ordinary frequencies. This fact led to the suggestion by others that insulators only slightly porous, after having been in service for several years so as to absorb moisture, might be discovered and weeded out before reaching a dangerous condition by subjecting them to a 60-cycle test at near flash-over voltage in order to line up the particles of moisture to form a conducting path, similarly to the lining up of particles of foreign matter between the electrodes in an oil testing set. Experiments were undertaken by a transmission company to apply this hypothesis, but the results obtained were negative in character so far as concerned substantiating the presence of porous ware. Such breakdowns as did occur could nearly always be traced to manufacturing defects in the porcelain.

Indications of Cracking. While the author has not had opportunity for the careful examination of any large number of faulty insulator units by the removal of the metal caps, such work has been done has afforded fairly consistent results. In order to remove the caps without disturbing the porcelain, a helical cut of suitable pitch is taken with a hack saw, beginning at the lower edge, which enables the metal at the side of the cap to be removed in the form of a strip, thus freeing the upper portion.

With the caps taken off it is still by no means an easy matter

Digitized by Google

to locate the existing cracks unless they have become opened up somewhat or are discolored through age. It has been found, however, that in some instances the cracks may be identified by carefully examining the surface of the cement which has been in contact with the porcelain. The cement may show a fine crack corresponding to the crack in the porcelain, or only darkened lines which for lack of a better term have been called "weathering lines". Such lines, marked by arrows, are shown in Fig. 1. In this view, the metal stud has been tilted slightly away from the camera to separate the weathering line from the edge of the porcelain, thus bringing it into better view. The line on the cement in the cap section has been produced from the same crack, as will be seen by comparing the two.

While the cause for the weathering lines is not definitely known, it is probable that they are the result of ozone liberated by slight electrical discharges through the crack while the unit was in service. Such discharges undoubtedly occur and their presence is borne out by a slight alteration often observed in the appearance of the surface of the fracture in the porcelain which becomes glossed and faintly iridescent when held to the light at the proper angle. This faint play of colors is not found on surfaces of pieces broken after removal from service.

Operating Problems

Deterioration in insulators is proceeding at such a rate that it is debatable whether all suspension insulators of the cap and stud type now in service will not have to be replaced within a comparatively few years. Obviously this constitutes a very serious situation for the operating engineer and it is imperative that insulators approaching the end of their usefulness be detected and removed from the line before conditions develop threatening the continuity of service.

The question arises as to whether anything will be gained by subjecting all insulators in service to a periodic test at high voltage for weeding out those pieces undergoing incipient deterioration. It is apparent that if a test could be devised which would insure safe operation for a period of three or more years without the necessity for attention to the insulators in the meantime, much of the cost of insulator patrol and maintenance of the lines would be obviated. It is believed that a high-voltage test might prove useful should it be established that porosity is a serious factor. On the other hand, it is not likely that much

Digitized by Google

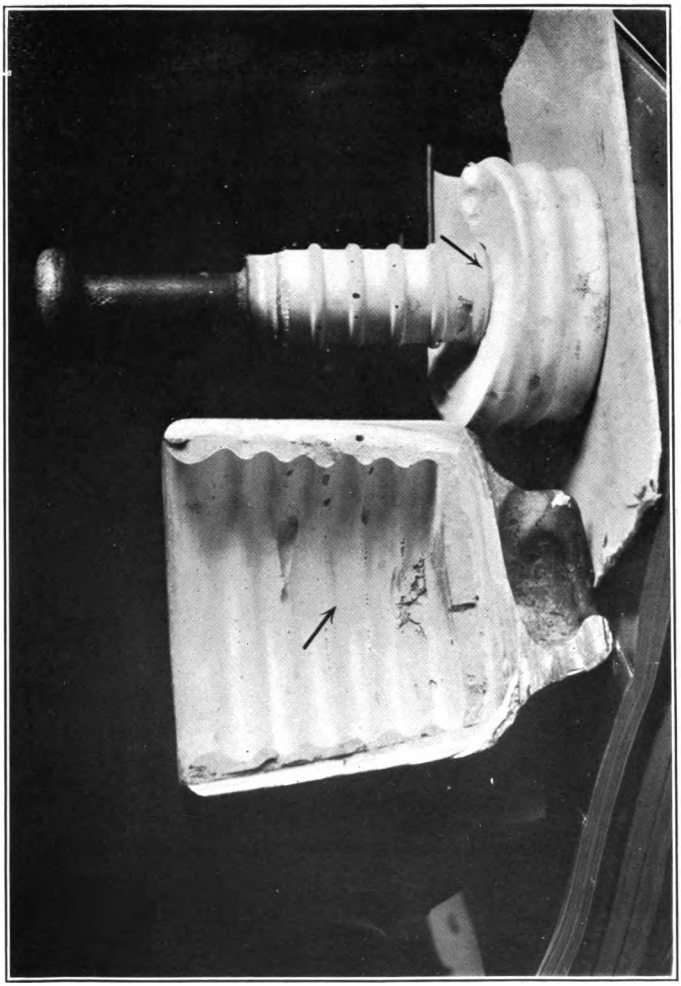


FIG. 1 [BRUNDIGE]

Digitized by Google

Digitized by Google

benefit would be derived from the testing of units in this way which are liable to deteriorate through cracking. It is known that each application of high potential will indefinitely continue to break down additional units and many of these would doubtless be of service for a considerable time before necessity arose in the ordinary course of events for their replacement. Moreover, failure by cracking proceeds at such a rapid rate that many of the insulators might make a good showing on test and fail very soon afterwards.

Conclusion

Summarized briefly, the reasons for believing that expansion effects are the principal cause for deterioration in suspension-type insulators are as follows:

1. The conditions existing inside the metal caps are sufficient to explain, through temperature expansion alone, much of the trouble experienced. Expansion occurring in the cement because of moisture absorption is of an even more serious nature.

2. No evidence of importance is at hand showing that electrical stresses have caused the trouble under discussion.

3. Except for bad cases of underfiring which are generally easily detected, losses of insulators in service do not bear any apparent relation to the degree of firing.

4. So far as observed, deterioration takes place quickly, such as would be expected during the formation of cracks. On the other hand, slightly porous ware absorbs moisture only very slowly, and were porosity the predominating cause for failure, large numbers of units would undoubtedly have been discovered in the intermediate resistance stages.

5. Cracks of more or less long standing have been identified in a majority of cases where it has been possible to carry on post mortem examinations on defective insulator units.

6. The relatively good showing made over long periods by pin-type insulators having cemented parts and by Hewlett units, none of which represent as high development of the porcelain manufacturer's art as some of the later suspension insulators, would indicate that porosity is not the factor of most immediate concern.

It is to be borne in mind, however, that after losses from expansion effects have been more or less completely eliminated, porosity in porcelain may remain as a problem of considerable importance and that the work done in this direction by investigators

Digitized by Google

will become increasingly valuable, unless perhaps a better material for insulators will then be available. Progress in overcoming expansion will doubtless include, as one of the steps, the elimination of Portland cement from the designs and this incidentally will be of aid in simplifying the problems arising from porosity.

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

THE INSULATOR SITUATION

BY W. D. PEASLEE

ABSTRACT OF PAPER

This paper gives a résumé of the insulator situation as it exists at the present time and shows the gradual increase in requirements that have been held essential to a successful insulator.

A statement of the apparent causes of the very rapid deterioration of insulators, even when stored and subject to no electric stress is given, and the conditions necessary to the production of an insulator that will reduce this deterioration cost are discussed.

Microphotographs showing the structure of the porcelain from several insulators are given. Interesting flows and defects common to porcelain insulators are shown. Three means are given for improving the insulator situation, one of which is the use of fused quartz as an insulator material, the laboratory feasibility of which has been shown. Investigations as to the commercial manufacture of quartz insulators are under way.

THE INSULATOR situation has for the last few years engaged the earnest thought of all engineers directly or indirectly responsible for the operation and maintenance of high-voltage transmission lines.

Not long ago the following general postulates were laid down by some operating engineers, despite the warnings of some research men, as the ultimate requirements of insulators for reliable service, and much was written in the technical press regarding efficiency as applied to line insulators with respect to these features.

1. The insulator must not flash-over at operating voltage even when dirty and wet.

2. The insulator should flash-over on excess voltage at normal frequency and not puncture.

3. Sufficient surface leakage distance should be provided to prevent excessive leakage current. (To prevent burning of wood poles and pins.)

4. It should be mechanically strong enough for the load imposed upon it.

Insulators by the carload have been made that meet fully those requirements, as far as normal frequency voltages are

Manuscript of this paper was received March 16, 1917.

Digitized by Google

concerned, that is, those that do not fail under factory test do. These new insulators, designed according to the best then existing engineering knowledge, were placed on our transmission lines and the insulator manufacturers began the study of making more and cheaper insulators while the engineers operating the lines began to get interested in other things, when the insulator situation again became of prime moment.

It was found that after about two or three years in service these insulators were failing at a rate of from 10 per cent to 40 per cent per year, apparently without logical regard to location or severity of service, climatic or electrical. Many very valuable and brilliant methods for detecting insulators about to fail were developed and the best that was hoped for was a chance to take them off when convenient before they went out at an inopportune time.

About this time a rather startling fact was discovered by several investigators almost simultaneously. If a certain lot of insulators, having passed successfully factory routine tests, are placed in a warehouse for a couple of years, a goodly per cent of them will fail at the end of that time on tests less severe than they passed to escape from the factory junk pile. In other words, they deteriorate at an alarming rate even doing nothing and apparently just "because". This experience the author can testify to with some regret, and it has been corroborated often enough, so that it is now a well recognized fact among workers in this field.

Not satisfied with the generally accepted theories in explanation of these failures the author began in 1914 an extended research into this field which finally led to the use of the microscope in an endeavor to ascertain, if possible, the mechanism of the failure of porcelain insulators. As a result of this microscopic work in connection with some experiments on transients, he laid down seven requirements in corroboration and extension of the four previously mentioned.

By the time this paper* appeared the work had been further advanced by means of an excellent high-powered petrographical microscope and the results lead to a decided doubt as to the ability of the porcelain insulator to meet the situation at all, even under the best conditions of manufacture.

From a study of the insulator troubles of several systems for the past three years, and from a microscopical analysis (using

*W. D. Peaslee, A. I. E. E. PROCEEDINGS, Aug. 1916, pp. 1237-1244.

Digitized by Google

polarized light and crossed nicols) of several hundred insulators whose records were known, the following points regarding the deterioration of the porcelain insulator seems to be pretty well established.

1. Perfectly good insulators that will pass all sorts of tests right after manufacture deteriorate at an alarming rate even when not in use. I have personally known of insulators stored in a warehouse, all of which have passed test on an oscillator, and also 60-cycle flash-over. Two years later 14 per cent of these insulators failed under 60-cycle flash-over. That is, they punctured at a voltage under the flash-over voltage.

2. It is very apparent that something takes place, inside the cap in a suspension unit, and between the shells in a pin-type unit, that causes this deterioration when not in service, though it is not impossible that the electric tests have some part in starting or causing some of this deterioration.

3. There seems also to be grounds for suspecting that in some manner certain insulators deteriorate at a rather rapid rate due to dielectric stresses combining with other stresses in such a manner as to materially hasten the failure of the insulator.

The results of the investigations seem to show that four factors are of predominant importance in this connection.

1. Mechanical stresses due to temperature changes necessarily resulting from the different coefficients of cubical expansion of the metal, cement, and porcelain; mechanical stresses due to the expansion of moisture in the cement on freezing and the changes in volume of cement with different moisture contents; and mechanical stresses due to improper firing and cooling of the porcelain.

2. Dielectric flux concentrations due to improper design of insulator shapes and defects in the porcelain. This can be remedied, but its general effect* is as has been shown, to permit the stressing of the porcelain to very high values by means of transients, which like the poor are always with us.

3. Dielectric flux concentration due to the fact that the porcelain is inevitably made of two or more materials of widely different physical properties, one isotropic and the others anisotropic in character, as strikingly shown by the microphotographs. It is well known that the dielectric constant or specific inductive capacity of an anisotropic medium is not the same in all directions but varies according to the angle between the principal optic

*W. D. Peaslee, A. I. E. E. PROCEEDINGS, Aug. 1916, pp. 1237-1244.

Digitized by Google

axis and the direction of the electric force. With the random alignment of the anisotropic crystals in a porcelain body, relatively large, minutely local flux concentrations result. While partially fluid in the process of firing, most insulator shapes develop flow lines wherein the crystals, anisotropic in nature, align themselves in such a manner that the permittivity of the dielectric along these flow lines is considerably greater than in other portions, resulting in definite flux concentrations along these flow lines.

4. Mechanical stresses due to the differences in coefficients of expansion of the constituents of the porcelain acting to establish a separation surface between the crystals.

Considering the cement, the volume changes of Portland cement under change of moisture content are well known, and examination of the cement in two hundred and eighteen insulators whose history was well known has shown the following facts:

All but fifteen of the insulators that had failed electrically (207) had cement whose absorption, after two hours baking at 120 deg. cent. and four hours boiling in water, was over 12 per cent and in some failing quickly the absorption ran up to 46 per cent. Of those which had failed mechanically or were still good (11) only one had cement whose absorption ran over 6 per cent.

While these data are no more than a surface indication they are offered as an indication of a possible source of deterioration. It can readily be seen that absorptive of such amounts of water the cement in such insulators must expand and contract viciously under temperature and humidity changes. Investigations are at present under way using various water-proofing compounds and different mixtures of cement to find the mixture that with a permissible strength sacrifice will give the lowest absorption. The preliminary results are encouraging and it is hoped that some valuable information will be available soon from these tests.

The porcelain from which insulators are made consists in the main of partially dissolved crystals of silica (SiO_2) in a ground mass of feldspar glass and crystals of sillimanite of a size depending upon the heat treatment of the porcelain. It has been found by some investigators that it is entirely possible and easy to determine within $\pm$ 25 deg. cent. the temperature at which a porcelain has been fired by the examination of a thin section under the microscope.*

*Technologic Paper No. 80 Bureau of Standards, Constitution and Microstructure of Porcelain.

Digitized by Google

Referring to Fig. 1 if the needles are anisotropic substances whose maximum permittivity occurs along the principal axis the resulting field distortion will be roughly as shown. Now combine a conglomerate mass of such needles scattered through a medium of different average permittivity still, and sprinkle through this a quantity of relatively large irregular anisotropic crystals of still different average permittivity and it will readily be seen that there are infinite possibilities for minute flux concentrations, and *whenever for a finite length of time the dielectric flux exceeds a certain value in a dielectric, the destruction of the dielectric is certain.* Also, failure of the dielectric heats it, and the negative temperature resistance coefficient of porcelain renders a progressive breakdown extremely easy when the initial failure occurs.

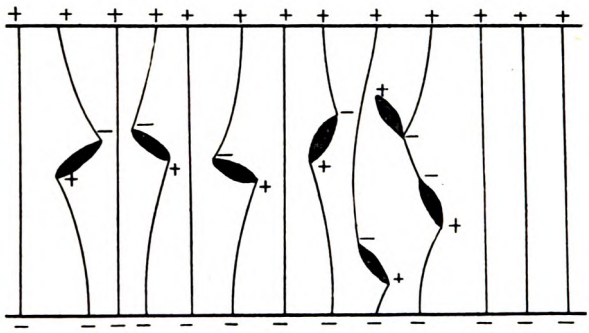


FIG. 1

Microscopic examination of a great many samples has shown that the flow lines mentioned are mechanically weak and have a great tendency to develop minute cracks, apparently during cooling. These cracks are often lined or filled with crystals of sillimanite (Al_2SiO_3) which are anisotropic and more or less in alignment. The combination of such cracks and the above mentioned flux concentrations along flow lines is a source of further weakness in the porcelain insulator. This point is brought out very clearly in several of the illustrations.

If the four factors last mentioned are the predominant ones in causing insulator depreciation we can of course lay out the requirements of an insulator that will avoid them.

1. A cement must be developed that will be elastic enough to take up the necessary changes due to expansion and contraction of the insulator parts under temperature changes. Condensite

Digitized by Google

and other compounds have been tried in this but so far as the writer knows, no positive results have been obtained that are as yet of commercial value.

2. Improve the design of the insulator to avoid flux concentrations and the placing of dielectric of different permittivities in series and improve the workmanship to avoid defects.

3. Make the insulator from an amorphorous, non crystalline substance, containing only one constituent, or only those of the same electrical and temperature characteristics.

Certain of the compounds that have been experimented on give promise of some success as a cement of the character described, and fused quartz except for inherent difficulties in working is ideal as an insulator material.

The temperature coefficient of expansion of fused quartz is about 0.000,000,59 or about one-fifth that of porcelain. Its dielectric strength is very high and its mechanical strength and elasticity are all that could be asked. It withstands indefinitely the action of high-frequency voltages such as those from the Poulsen arc and is to the action of the elements the most resistant material known.

Due to its low temperature coefficient of expansion an incandescent piece of fused quartz can be dropped into a pail of water without effect, except an apparent improvement in elasticity. This is a valuable property when it comes to running it into chilled molds.

The drawback is that it has a tendency to evaporate before flowing enough to mold and on fusing to explode and form a milky substance full of tiny air holes and useless as an insulator and is also chemically very active at extremely high temperaatures. Means of overcoming this have been found and until the microscope slides of the product were examined it was thought a perfect product had been secured, as the tiny carbon particles and bubbles so marked under the microscope in Fig. 10 and Fig. 11 are not visible to the unaided eye, merely giving the quartz a blue color. Means have been found to overcome even these defects and on a laboratory scale the manufacture of fused quartz as an insulator material is assured. The problem now engaging our attention is the production of this material in commercial sizes at a cost that will not be prohibitive.

Conclusion

A study of the growing mass of data on insulator deterioration, forces upon our attention the following insulator situation.

Digitized by Google

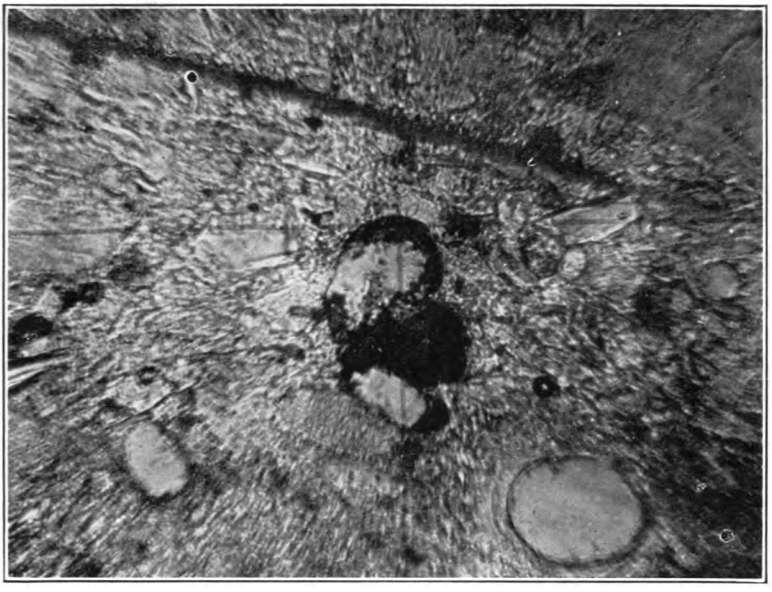


FIG. 2—300 DIAMETERS—TAKEN FROM AN INSULATOR MANUFACTURED IN 1912

This type has showed marked deterioration and has been removed from service by one company and replaced by another type—Note the shrink crack full of sillimanite crystals and the large partially resorbed quartz crystals showing in high relief—The darkness of the ground mass is caused by minute distributed sillimanite crystals—The darker bodies are aggregates of sillimanite with some kaolin.

FIG. 3—300 DIAMETERS—SAME AS FIG. 2 [PEASLEE]

Taken through crossed nicols showing anisotropic nature of quartz crystals (bright white masses) and of sillimanite (appearing as a light fog).

Digitized by Google

Digitized by Google

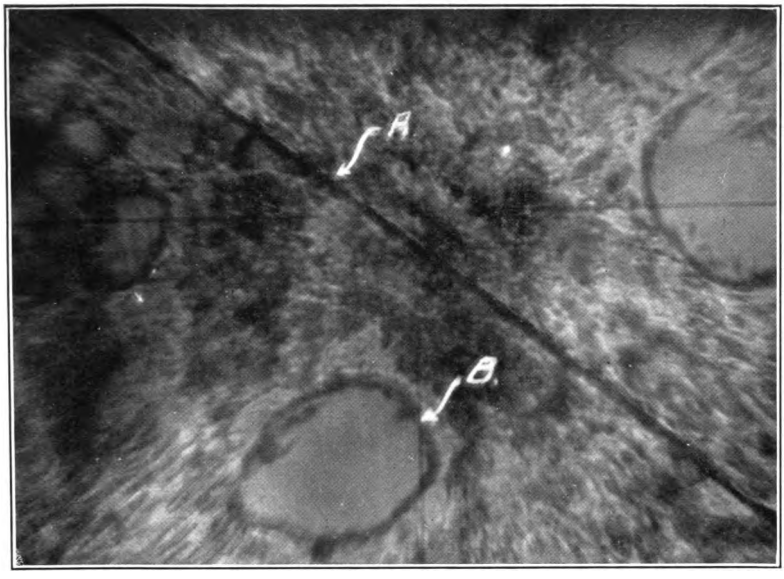
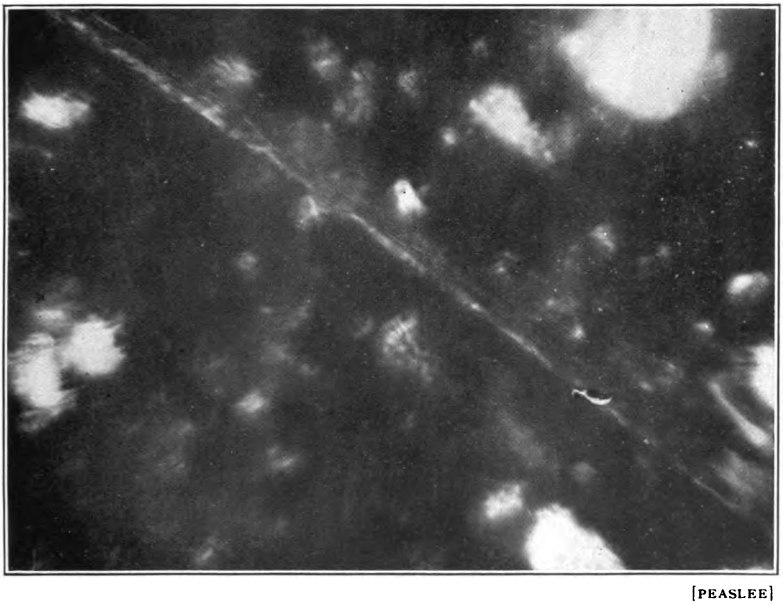


FIG. 4—300 DIAMETERS—SECTION FROM A WELL KNOWN MAKE OF HIGH-VOLTAGE PIN-TYPE INSULATOR

Failed under test before being put into service—A is crack lined with silliminate crystals—B is a large partially resorbed quartz crystal—The dark masses are sillimanite particles scattered through the glassy ground mass.



[PEASLEE]

FIG. 5—300 DIAMETERS—SAME AS FIG. 4 EXCEPT UNDER CROSSED NICOLS

The dark portion of this and other slides taken under crossed nicols is the isotropic feldspar ground mass.

Digitized by Google

Digitized by Google

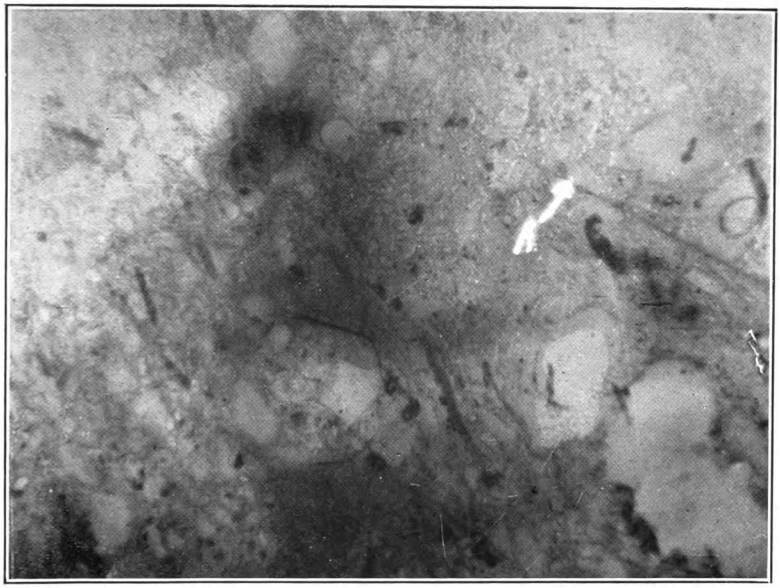
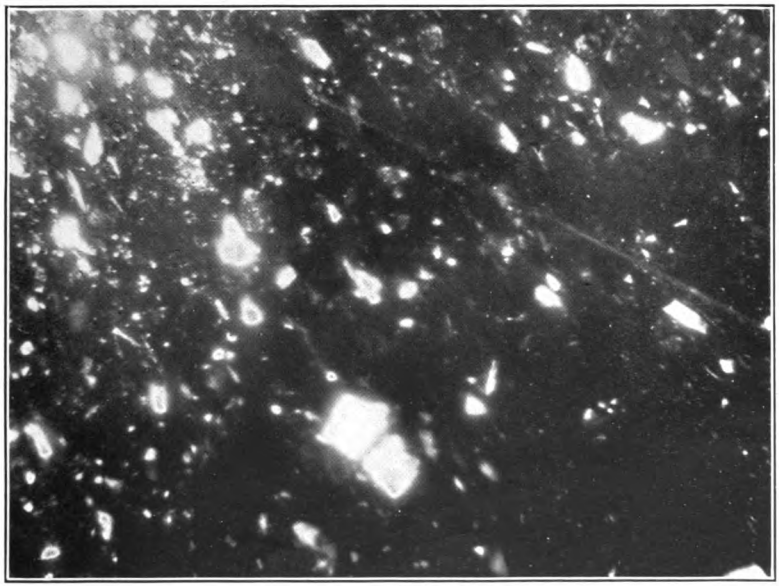


FIG. 6—300 DIAMETERS—SLIDE FROM AN INSULATOR THAT AFTER PASSING FACTORY TEST WAS STORED IN A WAREHOUSE TWO YEARS

Failed under flash-over voltage when taken out—The crack A is apparently due to expansion and contraction and is not a cooling crack as no crystals have formed in it—The cement in this insulator was very porous and showed the effects of expansion and contraction—Note the flow structure crossing the picture between the large quartz crystals and the alignment of sillimanite along this flow.



[PEASLEE]

FIG. 7—300 DIAMETERS—SAME AS FIG. 6 UNDER CROSSED NICOLS

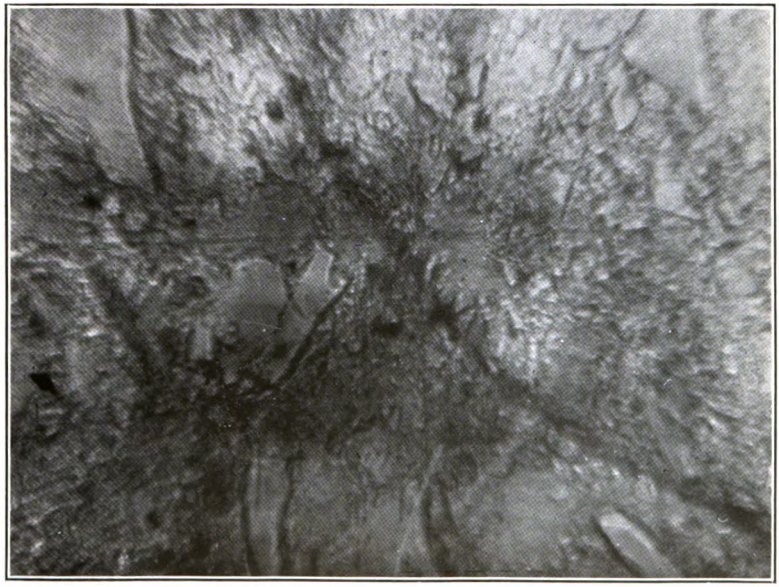
Note the great amount of fine quartz crystals and their concentration due apparently to flow in the mass before or during firing.

Digitized by Google

Digitized by Google

FIG. 8—300 DIAMETERS—TAKEN FROM A SUSPENSION UNIT REMOVED FROM THE LINE FOR LOW MEGGER READING AFTER ELEVEN MONTHS SERVICE

The insulator punctured below flash-over, 60 cycles—Note the very large quartz crystals partially resorbed and the large sillimanite crystal B and the short crack A lined with fine sillimanite crystals—This crack is only 0.01 inches long but is a potential weakness and this insulator was liberally sprinkled with them.



[PEASLEE]

FIG. 9—300 DIAMETERS—TAKEN FROM THE CURVE AT THE TOP OF THE INNER PETTICOAT OF A PIN-TYPE INSULATOR

Shows the crack curved to follow the curvature of the shell—This crack was about 0.25 inches long and about the center of the shell wall—This insulator failed after three months service.

Digitized by Google

Digitized by Google

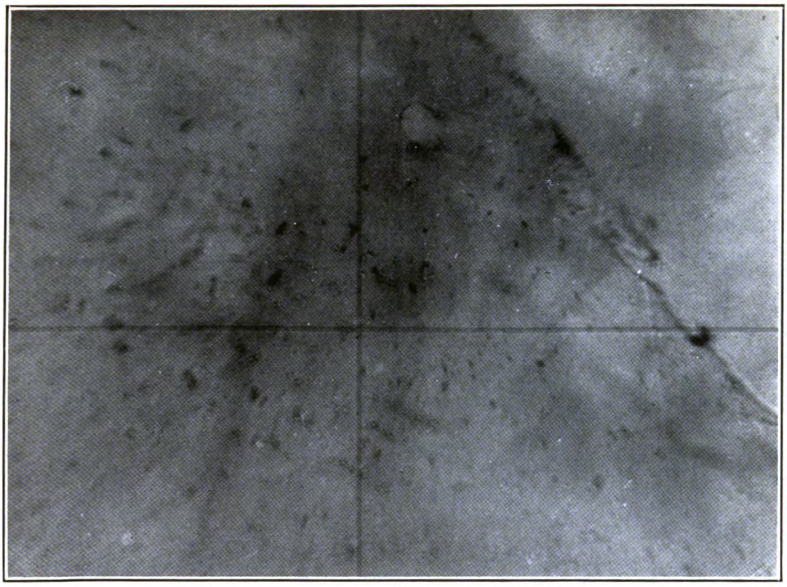
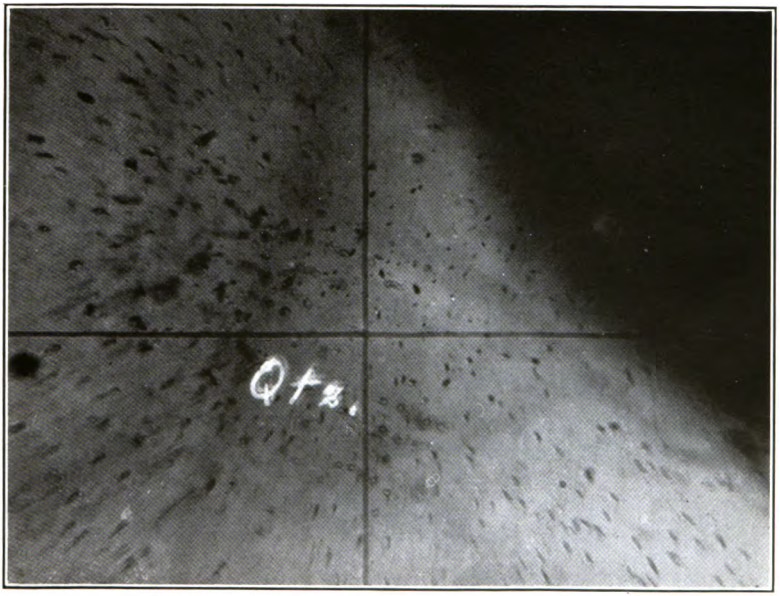


FIG. 10—300 DIAMETERS—FUSED QUARTZ MANUFACTURED IN SEARCH FOR A SUITABLE INSULATOR MATERIAL



[PEASLEE]

FIG. 11—300 DIAMETERS—SAME AS FIG. 10 EXCEPT UNDER CROSSED NICOLS

Digitized by Google

Digitized by Google

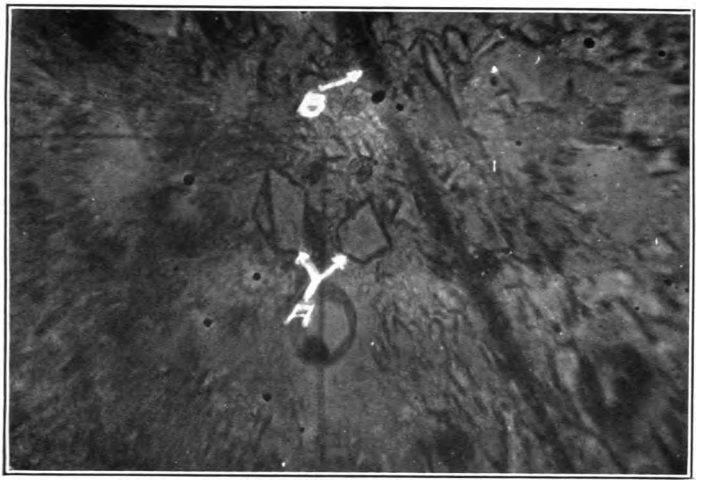
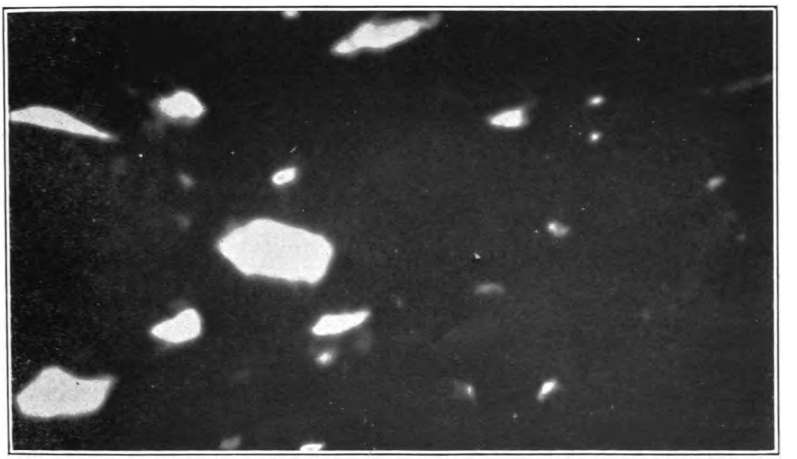


FIG. 12—300 DIAMETERS—CRACK IN A SUSPENSION UNIT THAT WAS REMOVED FROM THE LINE ON ACCOUNT OF LOW MEGGER READING



[PEASLEE]

FIG. 13—300 DIAMETERS—CROSSED NICOL VIEW OF SECTION FROM AN INSULATOR OF FOREIGN MANUFACTURE

Shows very clearly the isotropic ground mass (black) the anisotropic quartz (white) and the foggy masses of anisotropic sillimanite.

Digitized by Google

Digitized by Google

1. The porcelain insulator as commercially available today is not a success, it is deteriorating too rapidly both in and out of use and the gathered evidence points to certain inherent features of manufacture and composition that are responsible in large part for this unreasonable deterioration.

2. The design features may be overcome by a correct appreciation of the mechanism of breakdown and the application of correct principles of dielectric flux distribution.

3. It has been found possible to make and manufacture fused quartz on a laboratory scale and indications are that it can be done on a commercial scale for a permissible price, and it is hoped that the development of this and other studies now being made by many engineers may lead to a lessening of the enormous cost of the present insulator depreciation encountered by the operating companies.

The investigations herein mentioned have been made in the high-voltage laboratory of the Oregon Agricultural College and recognition is hereby expressed of the aid of Mr. A. Strieff, Assistant Instructor, and Mr. J. A. Hooper, a member of this year's senior class, both of whom rendered invaluable assistance in the many tests necessary to such an investigation.

Digitized by Google

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

PROBLEMS OF OPERATION AND MAINTENANCE OF UNDERGROUND CABLES

BY JOHN L. HARPER

ABSTRACT OF PAPER

The scarcity and high cost of transmission materials demands that the transmission capacity of electric underground cables be increased to a maximum.

The causes of failures of cables are analyzed and the conclusion drawn that overheating is the most important for consideration.

Methods of removal of heat from the cables are considered, and recommendations made for flooding the conduit with water, in order that the copper in underground lead-covered cables may approach the transmitting capacity of aerial cables.

THE COST of underground cables for power distribution has doubled within the past two years and operating companies feel loath to meet increased demands by the purchase of new cables at the present inflated prices, when it is not known that either demands for power or the increased prices of cables will be permanent. It, therefore, now often devolves upon the operating engineer to devise ways and means for working present installations to a capacity much greater than they were supposed to have.

Cable manufacturers have endeavored, from their experience, to give the purchaser some idea of the carrying capacity of the cables sold, but the first hand experience of the manufacturers usually ends with the delivery of the cable; hence the data and information given out have about the same relative reliability as those furnished by generator manufacturers for the capacity of generators in the days when such capacity was rated on the temperatures of the outflowing air instead of the temperatures of the inside hottest parts of the coils.

The fundamental causes of cable break downs have not been differentiated from local causes, as data and information acquired by individual cable manufacturers have usually been influenced by local conditions of installation and use, with the result that the fundamentals have not been clearly emphasized

Manuscript of this paper was received March 30, 1917.

Digitized by Google

and users with varying local conditions have received much misinformation.

For instance, many of the largest distributing systems using underground cables are in large cities where a very low load factor exists and there is a relatively small concentration of power delivery through any one conduit. Under these conditions, cables would naturally be given a higher rating than would be considered for places where they operate under a much higher load factor, as in the case of power distribution having the characteristics of the one with which the writer is connected, where the yearly load factor is in excess of 91 per cent and the daily load factor is in excess of 98 per cent. It is apparent that with this high load factor, cables have no chance to use off peak

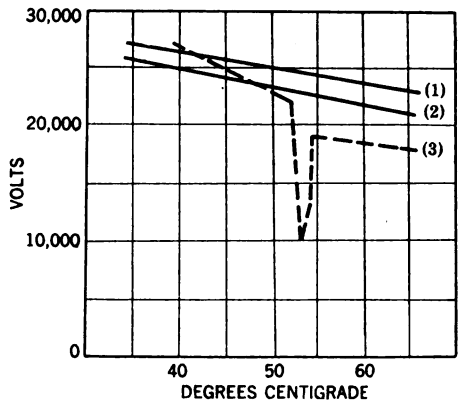


FIG. 1—(1) JOINT COMPOUND, (2) CABLE OIL, (3) MIXTURE OF 1 TO 1 JOINT COMPOUND AND CABLE OIL

periods to dissipate the heat accumulated during peak periods. The concentration of a large number of cables in one conduit also has a direct influence on their total capacity.

Assuming cables to be made of good material and with good workmanship and design, I venture to propose the following as the fundamental causes of failure, viz.: Joint troubles, mechanical injury to lead sheaths, and overheating.

JOINTS

Under this heading may be noted:

1. Those troubles which arise from improper making of the joint, due to improper workmanship, poor material, inexperience, etc., the remedy for which is principally accumulation of knowledge by actual experience and practise.

Digitized by Google

2. The incorporation of a joint filling compound that has not the same characteristics as the insulating compound used in the cable itself.

Cable insulation compounds are nearly always of a light color, while joint compounds are usually black. The mulatto combination of these two materials (each of which may be of the highest quality in its own clear unadulterated state) may produce a mixture having very different insulating characteristics from either of the original compounds. In the writer's experience, one whole system of cables had to be replaced on account of break downs in the vicinity of the joint wherever the cable insulation and the joint compound mixed. At that time a test was made of the insulating characteristics of the mixture for different temperatures and it was found that, while neither of the compounds in their clear form showed an insulation break down within the operating temperatures, the mixture did, and the curves in Fig. 1 show the relative conditions found to exist.

In a case like this, the operating engineer, being unable to wrench the secrets of the nature of the component parts of the insulating materials from the manufacturing company, was obliged to make further requirements of the cable manufacturer to the effect that he furnish a joint compound which would not show this objectionable effect. As the reinstallation of the cables under this method of procedure proved satisfactory and lasting, it has been assumed that in the privacy of the manufacturer's laboratory such changes were made in the joint or cable compounds that they maintained the high insulating characteristics even in the mixture.

Some expert joint makers contend that, if, in the handling of cables either at the factory or in the manhole, they are cut and allowed to hang down and bleed slightly, a bubble of air is liable to get into the cable, replacing the fluid which has bled. This bubble causes no disturbance until the cable is in operation and thoroughly heated up, when it may, by expansion, displace insulating compound and decrease the insulation at some special point, causing a slight leak of current with the resultant charring of the insulating materials and the production of a hot spot, whose temperature soon passes beyond the current resisting characteristics of the insulating material. This form of trouble often proves very elusive, as, in the case of the hot spot, as noted, if the cable is taken out of commission, cooled and again started up, the trouble may have moved several feet from the first loca-

Digitized by Google

tion, or may still be present in the cable even if the original hot spot is cut out.

Mechanical Abrasions

In regard to mechanical abrasions of lead sheaths, these troubles are positive and must show themselves sooner or later. The writer is not aware of any means of overcoming these troubles in cases where due care has been taken in the insulation of the cable, except to let nature take its course. If the conditions surrounding the operation of the cable are such as to force the early determination of these mechanical faults, the assurance of future continuous operation is greatly increased.

Overheating

The production of heat within the cables is a direct function of the square of the current transmitted as represented by the I^2R losses; and also of any dielectric loss, which is a function of the voltage and temperature of the insulating materials. Any heat produced in the cable must be dissipated through the insulating materials, the protective sheath, the conduit structures, and the surrounding medium, if the cables are to be kept at a temperature within the range necessary to maintain their insulating characteristics.

The paper of paper-insulated cables belongs to that class of materials whose insulating value decreases with the rise of temperature; therefore, within working limits, the cooler the cable is kept the less the dielectric loss.

An instance of the destruction of paper insulation under high temperatures was noted in taking out a length of cable in which a section, at least fifty feet from where any known trouble had existed, was found where the paper insulation had practically disappeared. The three conductors holding their relative positions for about two feet, the lead sheath being fully intact but only half filled with ashes from the destroyed insulation. This cable, while in operation had given no trouble at this place on a 12,000-volt working circuit.

The problem, therefore, resolves itself into a control of the dielectric loss and into an even and rapid dissipation of all heat produced within the cable. The retention of a constantly produced heat, no matter how small, would result in the building up of temperatures not only such as to destroy the insulating characteristics of the cable structures, but to destroy the cable itself.

Digitized by Google

It is apparent that the area of obstruction to rapid dissipation of heat from the cable or conduit may not be in the cable itself or in the conduit structures, but may be a factor of the quality and condition of the earth surrounding the conduit; thus, a cable system installed under the sod at the side of a paved street may have a very different radiation coefficient from a similar conduit under the pavement of the same street.

In a paper by Mr. L. E. Imlay in 1915 this matter was brought up, and the suggestion made of dampening the earth on the outside of the conduit by means of porous tile laid in the ground outside, which, undoubtedly, is a step in the right direction.

In the writer's experience, a 12,000-volt, 3-conductor, 4-0 cable was found to transmit 190 amperes per leg easily when the conduit contained but one cable, while this same cable could transmit only 140 amperes per leg with the same rise of temperature through the same conduit when other similar cables had been added and were all connected in parallel. This would indicate that, in the particular instance noted, which was through clay soil and under a paved street, the obstruction to the dissipation of heat was in the earth surrounding the conduit structure. It was also noted that in this conduit, which was made up of nine ducts, an installation of eight cables in the outside ducts would transmit practically the same amount of power for the same rise of temperature as would be transmitted when the ninth cable was installed in the central duct. This indicates that any conduit has a total carrying capacity dependent upon the exterior surface of the conduit structure in contact with the surrounding earth. In Niagara Falls, under paved streets, in clay soil, and without artificial cooling, the capacity of any one conduit system is restricted to approximately 30,000 horse power.

That a cable may for a short time, without permanent injury carry power far in excess of its ordinary capacity was shown by a case where seven cables were furnishing power to a customer. A short circuit occurred that opened the breakers on six of these but the seventh failed to open. The needle of the dial on the instrument of the switchboard not being in sight, the operator did not notice that it had disappeared at the upper end of the scale, and he, therefore, left the cable in circuit while waiting advice from the plant to again put on the power. This not being received in the ordinary time, he called up and found that the customer was not cut off. An examination of the recording wattmeter indicated that the seven cables were delivering

Digitized by Google

approximately 22,000 kw., that when the six were opened the power dropped to 18,000 kw. and gradually ran down during a time of 17 minutes to 9,000 kw., at which time it was taken out of service by the station operator. On examining this cable in the conduit it was found to be extremely hot and with several of the joint sleeves broken from internal pressure of compounds or gases. Upon cooling it down, filling up and resealing the joints, the cable was again put in operation and has been doing its work satisfactorily for four years.

In a recent construction of a hydroelectric power plant a saving of $500,000 was made on the first cost by adopting a speed of 300 rev. per min. instead of 180 rev. per min.; therefore, why should not a similar effort be made to decrease the first cost of conduit and cable distributions of power by speeding up the dissipation of the heat formed by the I^2R losses, at least to the point where in any cable system, the power value of the I^2R losses may be made to balance the operating expense of increased construction and installation.

It is, therefore, suggested that the dissipation of heat by water be applied to new and permanent construction and that, in places where such construction is possible, conduit systems should be built so that the ducts can be flooded with water and cables operated under practically submarine conditions. Bare copper wires in aerial transmission lines now carry approximately twice the current that is carried in the corresponding conductor of an underground paper-insulated cable and, if the lead sheath of the cables were kept at a temperature below 60 deg. cent. by the presence of water, the carrying capacities of underground cables could be made to nearly approach that of bare aerial conductors.

The rapid and definite dissipation of the heat from the cables with water immediately surrounding them would not only greatly increase the carrying capacity of any particular cable or of a particular conduit system, but would decrease possibilities of cable trouble from all other causes except mechanical injuries of the lead sheath.

Digitized by Google

Presented at a meeting of the Schenectady Section of the American Institute of Electrical Engineers, Schenectady, N. Y., May 4, 1916.

Copyright 1916. By A. I. E. E.

ILLUMINATION OF THE PANAMA-PACIFIC INTERNATIONAL EXPOSITION

BY W. D'A. RYAN

ABSTRACT OF PAPER

In this paper the author, who was Chief of Illumination for the Panama-Pacific International Exposition in San Francisco, describes the system of lighting adopted for the Exposition, which was generally conceded to have initiated a new era in the art of illumination. From a narrow engineering point of view the lighting would have been regarded as inefficient, but the object striven for was to suppress high intrinsic brilliancy, while bringing out the architectural beauties of the Exposition structures in the most effective manner, bathed in a harmony of color. Many beautiful effects were obtained by the various installations which are described, and one of the most original features was the successful effort to preserve the curvature and detail in relief by the use of lights of different strengths and colors thrown from different or opposite directions upon the same object.

THE illumination of the Panama-Pacific International Exposition was finally classed by the International Jury of Awards as a "decorative art", largely because it appealed to the imagination and feelings of the masses, and carried a message much the same as painting or music, as demonstrated by the happy enticing effect of the heraldic banners on the Avenue of Progress, the deep mystery in the Court of Abundance, the grandeur and uplifting effect of the great candle-fountains in the Court of the Universe, the quiet peaceful illumination in the Court of the Four Seasons and on the Palace of Fine Arts, the Alladin dreams and fairy-like suggestions of the illuminated towers, flags, reflections and other features which made up the lighting as viewed from the South Gardens.

In this connection I wish to quote Edwin Markham's impressions gained on try-out night, February 15, 1915:

"I have tonight seen the greatest revelation of beauty that was ever seen on the earth. I may say this, meaning it literally and with full regard for all that is known of ancient art and architecture, and all that the modern world has heretofore seen of

Manuscript of this paper was received July 24, 1916.

NOTE: The colored illustrations for this paper were supplied through the courtesy of the Schenectady Section of the American Institute of Electrical Engineers.

Digitized by Google

glory and grandeur. I have seen beauty that will give the world new standards of art and a joy in loveliness never before reached. This is what I have seen—the courts and buildings of the Panama-Pacific Exposition illuminated at night."

The illumination of the Exposition was based on developments of the science of lighting, and represents results of personal experience in this field extending over a period of twenty years.

The lighting for the Exposition was completely designed in the latter part of 1912 and every feature was carefully calculated, as there was practically no opportunity for trial, owing to the radical nature of the scheme and scope. The buildings of previous expositions had in the main been used as a background upon which to display lamps. The art of incandescent outlining, notably the beautiful effects obtained at the Pan-American Exposition at Buffalo, could probably not be improved upon, and furthermore, this form of lighting had been extended to amusement parks throughout the world and had become commonplace. Its principal disadvantages were the diminution of artistic effectiveness at close range, similarity in effects from different view-points, the suppression or complete obliteration of architectural features, and the economic necessity of extensive untreated surfaces. Furthermore, the glare from so many exposed sources when assembled on white or light-colored buildings, caused severe eye strain.

The lighting scheme and scope of the Panama-Pacific International Exposition called for a radical departure from previous practise. Incandescent outlining on the main group of palaces was avoided, and screened or masked flood and relief lighting to produce the third dimension or depth, substituted, and great care was exercised to preserve the architectural features and color, with proper relative intensities. For the first time at an international exposition, the illuminating sources, whether arcs, incandescent or gas, lost their identity as such. While a uniform system was maintained throughout, each court possessed its individual characteristics with radical differences, and at the same time the transition from one effect to another was harmonious, even to the extent of an intermediate step or carnival effect on the Avenue of Progress connecting the Zone and the main group of palaces.

During the pre-exposition period, there were many who maintained that the general public would not be attracted except by the glare of exposed brilliant sources. The lighting of the Ex-

Digitized by Google

position, however, immediately disproved this theory and a strong psychological appeal was made by the highly artistic lighting effects.

During the period elapsing between the Louisiana Purchase Exposition and the Panama-Pacific International Exposition, wonderful advances had been made in the efficiencies of all types of lighting units. This made it possible to illuminate in the main group of buildings, approximately 8,000,000 sq. ft. (743,200 sq. m.) of horizontal and vertical surfaces to an illumination ranging from 1/10 to 1/4 of a foot-candle in the incidental gardens and roadways, from 1/4 to 3 foot-candles in the building facades and adjacent lawns and gardens, and from 5 to 15 foot-candles on the towers, flags and sculptural groups. The lighting load on the main group of buildings, including the window lighting and the scintillator, was approximately 5000 kw. The total connected load for all purposes, including Zone, Foreign and State sections and exhibitors, for light and power, was 13,954 kw., with a maximum peak of 8200 kw. and an average peak of 7880 kw. During the Exposition period of approximately ten months, a total of 16,057,790 kw-hr. was purchased from the Pacific Gas and Electric Company. Of this amount, 5,582,906 kw-hr. were sold to exhibitors and concessionaires, the remaining 10,474,884 kw-hr. being used by the Exposition.

While the lighting of the Exposition was primarily electric, all modern sources of intrinsic merit were used, and a number of excellent gas features were introduced. About four miles of streets in the Foreign and State sections were illuminated with Penn globe high-pressure gas "arcs," in 20-in. (508-mm.) opal globes mounted with their centers about 16 ft. (4.9 m.) above the roadways on ornamental poles spaced approximately 100 ft. (30.5 m.) apart, staggered. The same type of lamp was used for emergency lighting on the kiosks throughout the grounds. Five-mantle Humphrey gas "arcs" enclosed with ornamental lanterns were used in pairs on the standards in the Zone (amusement section) and the same type of lamp, of smaller sizes, furnished emergency lighting at the gates and important exits from the main group of buildings. Gas flambeaux were introduced in the effects in the Court of Abundance and the North Approach. The total gas flow for the purposes mentioned was approximately 15,000 cu. ft. (425 cu. m.) per hour. The average amount of gas consumed daily at the Exposition for all purposes was 486,550 cu. ft. (13,780 cu. m.). The total amount purchased by the Exposition Company during the

Digitized by Google

Exposition period was 121,913,500 cu. ft. (3,452,590 cu. m). Of this amount only 25,101,496, cu. ft. (710,874 cu. m.) was used by the Exposition Company, the remainder being sold to exhibitors and concessionaires.

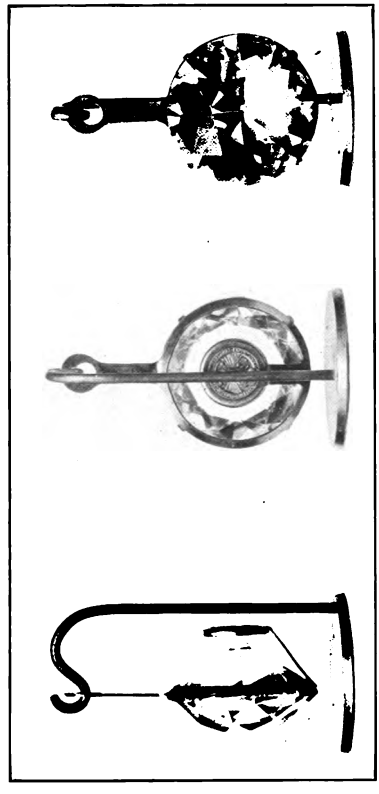
In order to obtain a harmonious illumination scheme, it was necessary to visualize the lighting as a whole, and to establish illumination and color values for every part of the Exposition before definite specifications for lighting equipment could be made. The preliminary tests and calculations on lighting units that had been selected for use at the Exposition were made at the Illuminating Engineering Laboratory. The work of calculation was greatly shortened and simplified by the use of various graphical charts, one of which, an illumination chart, is described by Mr. Frank A. Benford, Jr., in the *Transactions* of the Illuminating Engineering Society*. The lighting units were all new developments, in many cases used in new ways. This necessitated a vast amount of preliminary investigation which usually took the form of calculations of the illumination on the grounds, facades and towers. From these calculated values it was possible to determine if the selected lighting units were of the right size and were properly arranged on the preliminary plans. As soon as any particular phase of the lighting was fully decided upon, the illumination and luminous flux values were calculated in all their minute details, so that long before the Exposition opened there were on hand complete sets of illumination diagrams for all the various courts, buildings and towers. Some of these diagrams are illustrated by Figs. 7, 8, 16, 20 and 23, which are referred to later.

The principal features of the lighting are described under their respective headings and illustrated by the accompanying plates.

Luminous Effects in Tower Illumination. This illumination consisted in flood-lighting the towers with a white rising light which created shadows. The shadows were in turn illuminated by concealed colored light on the various stages, thereby producing detail in shadow. This combination gave the structures a luminous effect never before obtained. These towers further illustrated the preservation of depth, or the third dimension in light, which feature predominated throughout the Exposition. The Tower of Jewels was flood-lighted by batteries of arc projectors located on the roofs of the main group of palaces, the

*Vol. VII, page 695, 1912.

Digitized by Google



[RYAN]

FIG. 1—NOVAGEMS MOUNTED IN BRASS HOLDER

Digitized by Google

Digitized by Google

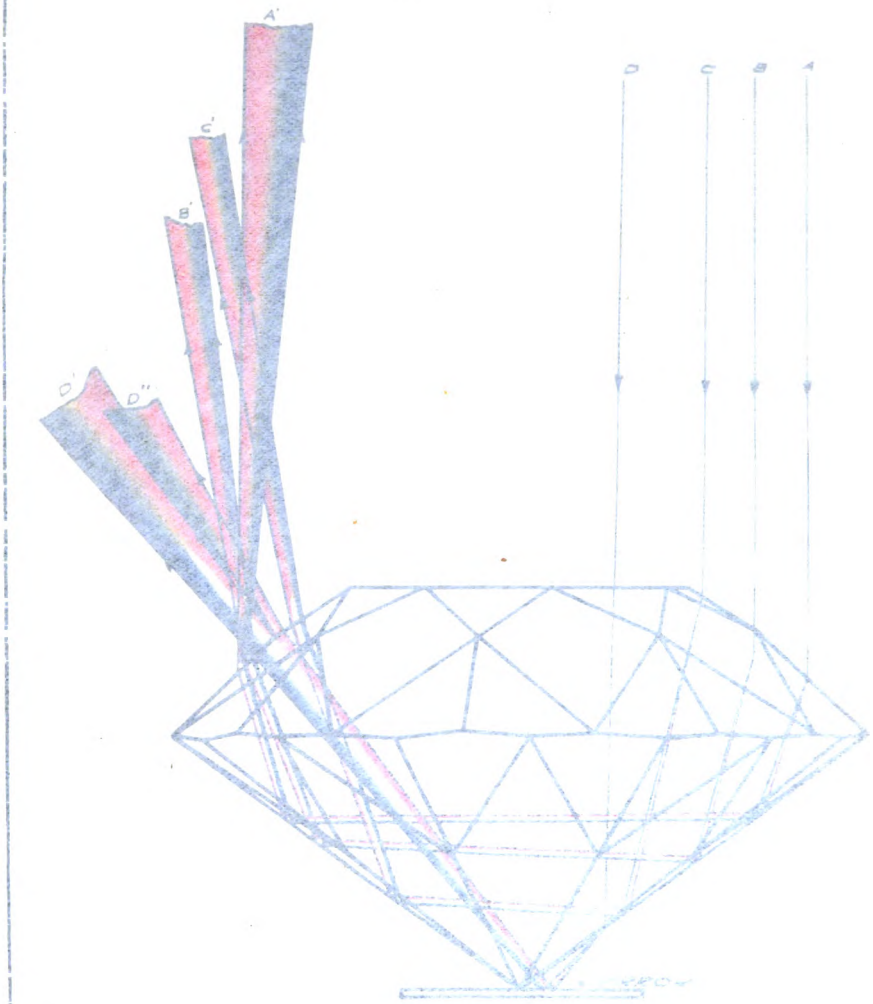
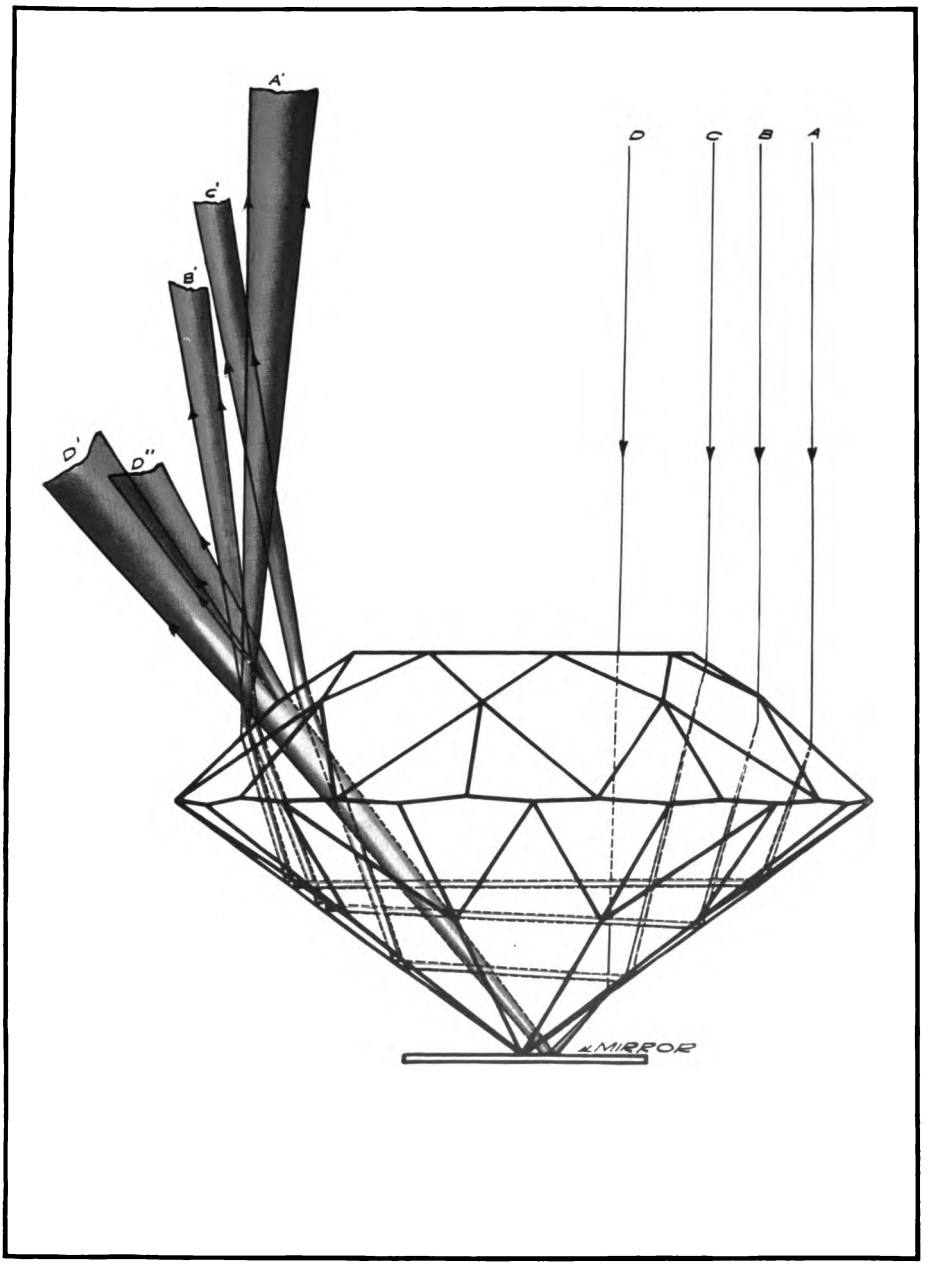


Fig. 2—Breaking Up of Incident Light Passing Through Novagem Jewels

Digitized by Google

Fig. 2—Breaking Up of Incident Light Passing Through Novagem Jewels

Digitized by Google



Digitized by Google

Digitized by Google

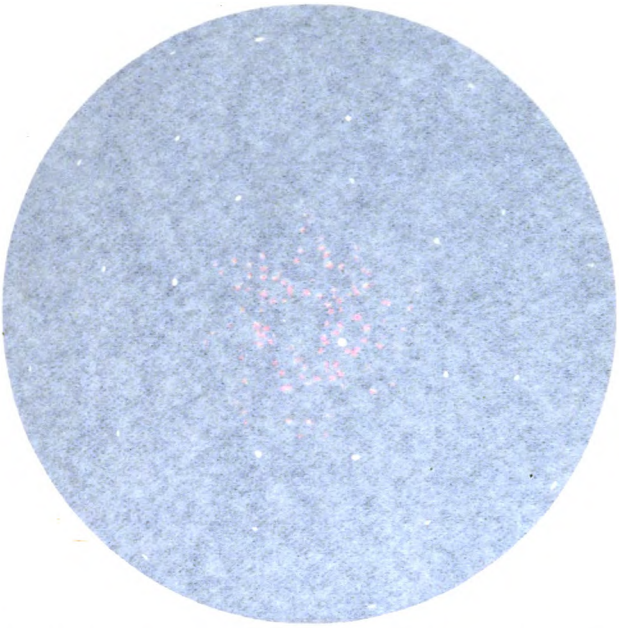


Fig 3—Spectra Produced by Single Beam of Light

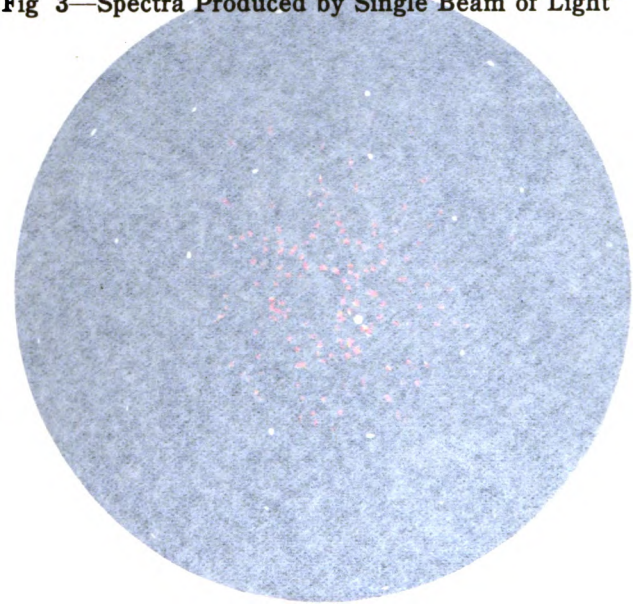


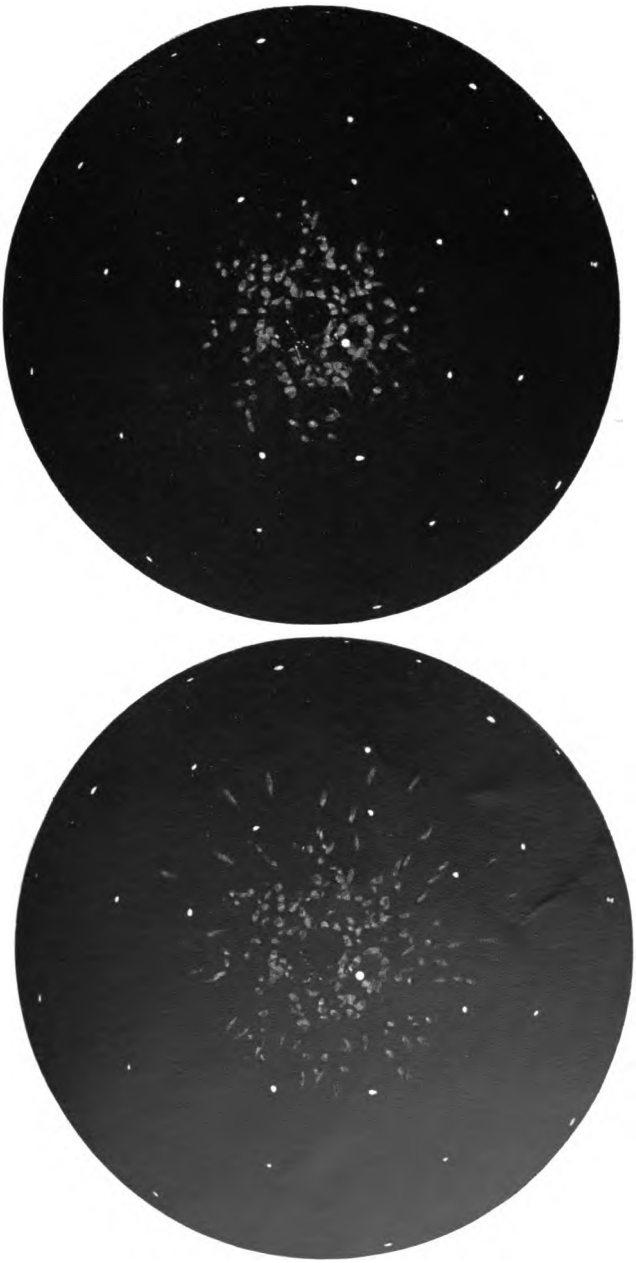
Fig. 3A—Increased Spectra Due to Use of Mirror

Digitized by Google

Fig 3—Spectra Produced by Single Beam of Light

Fig. 3A—Increased Spectra Due to Use of Mirror

Digitized by Google



Digitized by Google

Digitized by Google

South Garden pavilions and the Scott Street entrance gate. In order to obtain the proper gradation of light with an economic distribution, it was necessary to equip the majority of the projectors with properly designed diverging doors. A complete set of color screens at each projector enabled the changing of the color tone of the tower on very short notice. The base section was necessarily carried in the same relative illumination as the building facades. Above this section there was a rising illumination to approximately 20 foot-candles on the top ball. The average value for all levels was 10 foot-candles. The shadows cast by the rising searchlight beams were illuminated by rose red relief lighting. At the top level there were four 30-in. (762-mm.) arc projectors equipped with changeable color screens for spectacular and heightening effects. The twin Italian towers at the entrances to the Courts of Palms and Flowers were lighted in a similar way.

"Novagem" Jewels. "Novagem" jewels are scientifically cut glass of high index of refraction, made to imitate diamonds, rubies, sapphires, emeralds, etc. Each was mounted in a suspension carrying a mirror at the apex of the stone, which increased the spectra approximately forty per cent. These jewels were used to carry architectural lines in addition to being massed on shields and other points. They were mounted in such a way that they were kept in motion by the wind, thereby adding action to the effect when illuminated with projected light, which, especially in the white stones, produced all the colors of the spectrum with unusual purity. 102,000 47-mm. diameter jewels were used on the Tower of Jewels, and about 4000, in sizes from 21 to 47 mm., were hung on the star heads of the seraphic figures in the Court of the Universe. Fig. 1 shows one of the novagems mounted in the brass holder. Fig. 2 illustrates the breaking up of the incident light passing through one of the 47-mm. stones. Fig. 3 is a reproduced from a photograph of the spectra produced by a single beam projected normal to the plane of the table. Fig. 3A shows the increased spectra due to the use of the mirror.

The following table gives the indices of refraction, specific gravity and weight of the 47-mm. stones:

Indices	Specific gravity	Weight, 47-mm.
Yellow.....1.669	3.925	0.235 lb. avoir.
White.....1.616	3.589	0.221 lb. "
Pink.....1.618	3.595	0.216 lb. "
Ruby.....1.618	3.87	0.237 lb. "
Amethyst.....1.616	3.55	0.234 lb. "

Digitized by Google

The Electric-Steam Color Scintillator. The scintillator consisted of combining searchlights in systematic drill in colored and white beams with smoke and steam, so as to produce spectacular

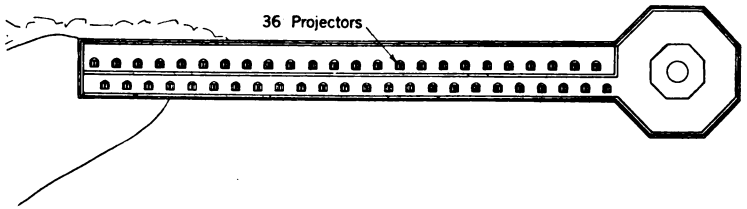


FIG 4—ELECTRIC COLOR SCINTILLATOR

effects or fireless fireworks, both aerial and on the ground, possessing artistic color combinations and blendings impossible with ordinary fireworks. This was further enhanced by the running of a large express locomotive at high speed under brake so as to

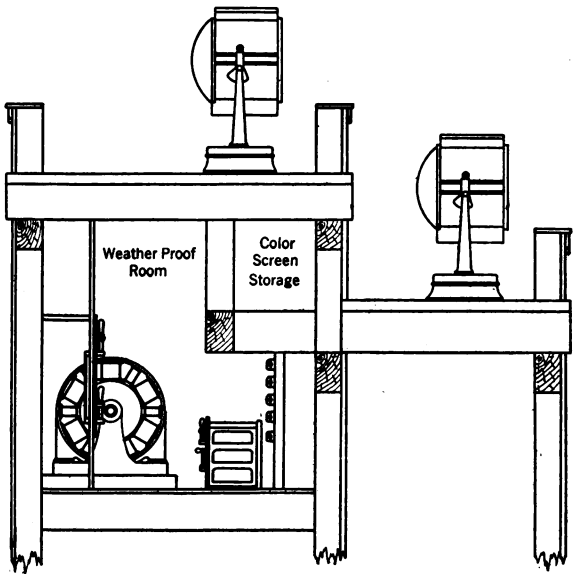


FIG. 5 — CROSS SECTION OF ELECTRIC COLOR SCINTILLATOR

produce large volumes of smoke and steam which were illuminated in color. Other steam effects were in the form of fans, plumes, wheels, fighting serpents, etc. This battery was composed of 48 36-in. (914-mm.) hand-controlled arc projectors. They

Digitized by Google

were operated at nominal 110 volts, 110 amperes, and with the resistance consumed a total of 581 kw. The beam candle power of each was approximately 55,000,000, or an aggregate of 2,640,000,000 for the battery. With the equipment of each projector was a set of seven colored gelatine screens, treated with spar varnish and turpentine as a protection against moisture.

These searchlights were located on the double deck pier on the north breakwater of the yacht harbor (Fig. 4), which was constructed as shown by the cross-section drawing (Fig. 5). Part of the space below the upper deck was used for housing the color screens, resistance boxes and distribution system, as well as a 250-kw. motor-generator set (see photographs) which supplied part of the power for the projectors. The remainder of the power necessary was taken from a 1000-kw. set located in the Palace of Liberal Arts.

The locomotive, steam apparatus and fireworks mortars were located on the south breakwater of the yacht harbor (Fig. 6).

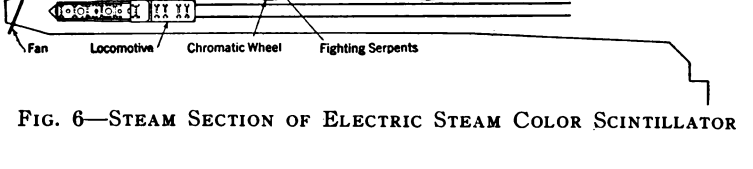


FIG. 6—STEAM SECTION OF ELECTRIC STEAM COLOR SCINTILLATOR

In addition to supplying the various steam effects such as plumes, chromatic wheels, fairy feathers, etc., this locomotive, which was a modern Southern Pacific oil-burning passenger type, was blocked up and locked so that the wheels could be driven at a speed of 60 miles (97 km.) per hour under brake. Thus great volumes of steam and smoke were produced, which, when illiminated with various colors, created a wonderful spectacle.

Banner and Cartouche Lighting Standards. The banner standards consisted primarily of anywhere from two to nine ornamental luminous arcs mounted on 25- to 55-ft. (17- to 7.6-m.) shafts, the lamps being screened by banners in such a way that they flood-lighted the buildings, lawns, trees and shrubbery, and at the same time, the direct source was not visible in the main vistas. These banners, which formed decorations by day and beautiful spots of color by night, were hung so that they moved in the wind, adding action to the effect. At the same time, they were weighted and guided in such a manner that they did not

Digitized by Google

expose the source or become self-destructive by whipping. As a matter of further interest, the history of California and the Pacific ocean was written in the designs on the three-, five- and seven-light banners, by the use of the heraldic shields of the early explorers and pioneers. The banner standards were used

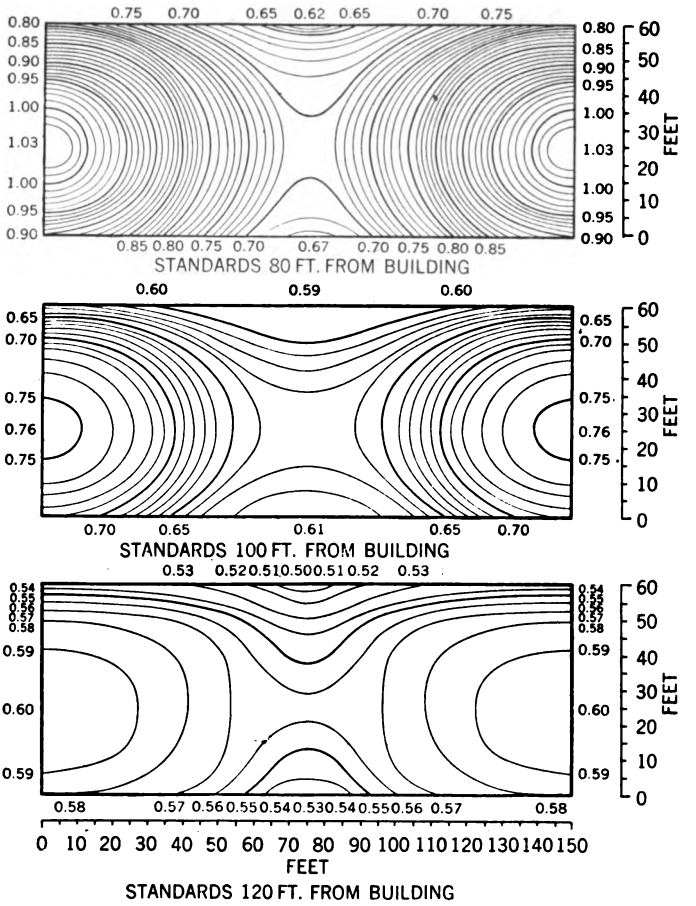


FIG. 7—ILLUMINATION ON EXTERIOR OF BUILDINGS—FIVE LIGHT STANDARDS

Light reflected from banners adds 20 per cent to the above values

for flood-lighting the Court of the Four Seasons, the Palace of Horticulture, Festival Hall, all palaces fronting on the Avenue of Progress, and the central group on the Avenue of Palms.

The three isolux diagrams shown in Fig. 7 give the foot-candle values obtained in preliminary calculations for the illu-

Digitized by Google

mination of the exterior facades of the main group and furnished a basis for estimating the number of lamps required for general surface illumination. Fig. 8 shows a preliminary curve of foot-candle values calculated for the building facades within the Court of the Four Seasons. The photometric test values taken under operating conditions checked very closely with these original calculated values.

The cartouche standard was of he same order as the banner standards, except that painted translucent fabric was used in place of canvas, which was not free to move, being held rigidly in the cartouche. In addition to screening the direct light from the people, it created pleasing spots of color in contrast with the

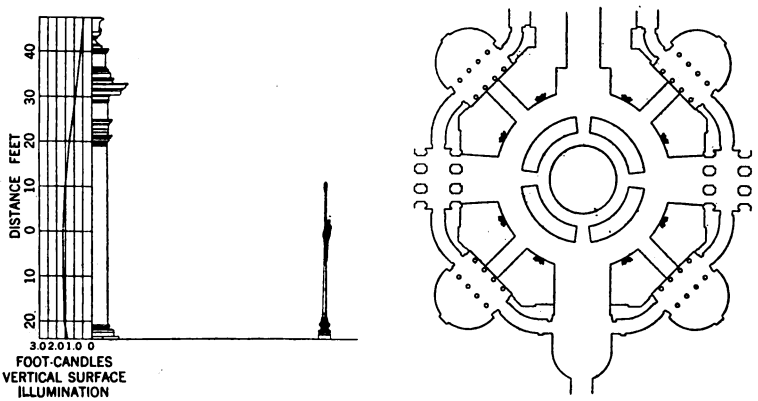


FIG. 8—VERTICAL SURFACE ILLUMINATION—COURT OF THE FOUR SEASONS

walls of the buildings and supplemented, with the banner standards, the flag illumination or sky line effect.

The flags on the buildings fronting on the Avenues of Palms and Progress were individually lighted by 13-in. (33-cm.) arc projectors, 100 units being used for this purpose. Economic reasons necessitated the designing of an incandescent projector for the lighting of the flags on the north and west walls and in the courts. This unit (Fig. 9) was constructed of an 11-in. (28-cm.) diameter parabolic mirror surrounded by a double row of small plain mirror panels which extended the parabola, thus increasing the efficiency. Two hundred projectors of this type with 500-watt mazda stereopticon lamps were used.

Electric Kaleidoscope. The electric kaleidoscope was designed to create exterior effects on the glass dome of the Palace of Horti-

Digitized by Google

culture, such as revolving bars, rings and spots in astronomical movements or the dissolving of colors from one shade or tint to another, without a sharp line of demarcation.

It consisted primarily of a battery of twelve 30-in. (762-mm.) arc projectors, arranged around a central structure as shown in the plan view, Fig. 10. The light from these twelve projectors passed through a common orifice in the top platform of the structure, at which point were located specially cut revolving interchangeable lenses. Before passing through the lenses the projected beams of light were intercepted by revolving color screens and shadow bars. Each one of these units was operated by an individual mechanism and independently of one another, as shown by the photographic and elevational view in Figs. 11

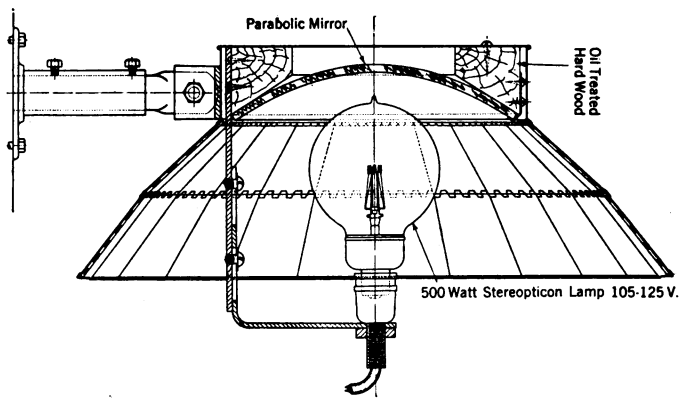


FIG.—9 FLAG LIGHTING UNIT

and 12. The different types of lenses were made up in sets of four separate quadrants (Fig. 13), which permitted the use of any combination of lenses desired at the same time. With this flexibility of lens combinations, together with the interchangeable color screens and shadow bars, it was possible to obtain a variety of effects.

N. B. The glass in the dome of the Palace of Horticulture was not in accordance with specifications. The results, while generally satisfactory, could not come up to anticipations, due to the lack of sufficient diffusion in the glass.

Indirect Lighting for Large Auditoriums. This lighting is applicable to large auditoriums or large places where concealed lighting is desired, but where the dome or ceiling construction does not permit the use of it. The system consists of placing a

Digitized by Google

battery of searchlights beneath the main floor and concentrating the beams on a diffusing plate in a central screened opening for re-distribution to the ceiling.

This was demonstrated by the installation in Festival Hall before the building was converted into a theater. Twelve 18-in. (457-mm.) projectors were used, giving a combined beam candle power of approximately 114,000,000. Inasmuch as a

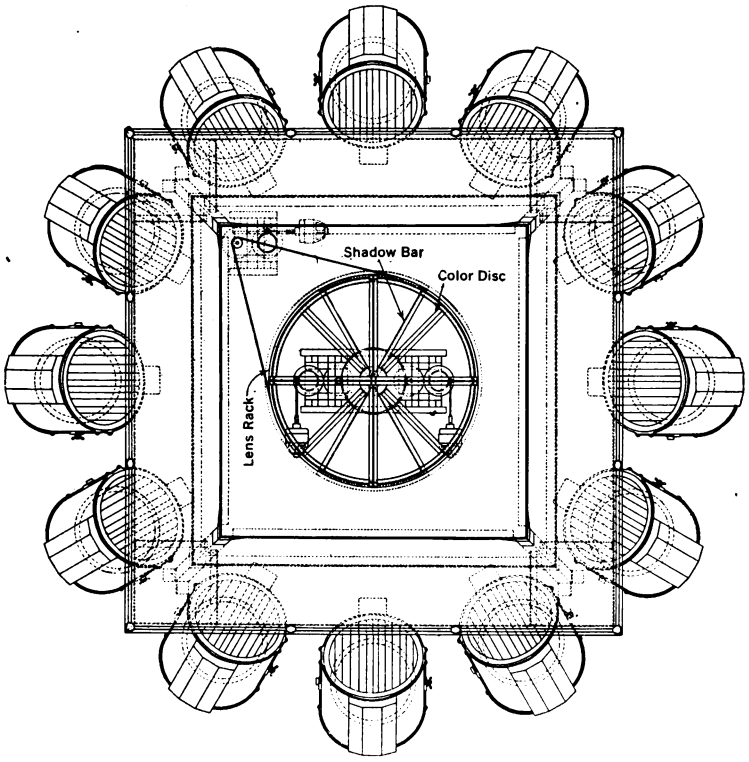


FIG. 10—PLAN VIEW OF ELECTRIC KALEIDOSCOPE—PALACE OF HORTICULTURE

large city sewer ran directly underneath the center of the building, it was necessary to locate the projectors in respect to it, as shown in Figs. 14 and 15. Fig. 16 shows a preliminary calculated illumination curve for the ceiling and walls.

Non-Glare Art Gallery Illumination. In the lighting of the Palace of Fine Arts a system was designed whereby the lamps were placed above the skylight and around the perimeter. By

Digitized by Google

the combination of a suitable angle reflector and the proper diffusion glass a good general distribution was obtained on the hanging surfaces, and specular reflection was further reduced

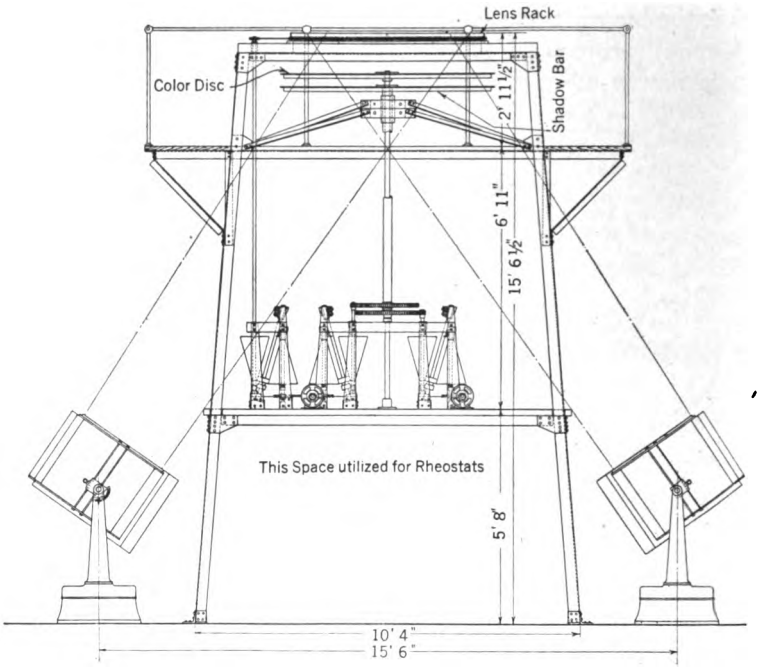


FIG. 11—ELEVATION OF ELECTRIC COLOR KALEIDOSCOPE—PALACE OF HORTICULTURE

by the use of shadow curtains on the under side of the skylight. For economic reasons the shadow curtains were finally omitted. This system of lighting has considerable advantage over the

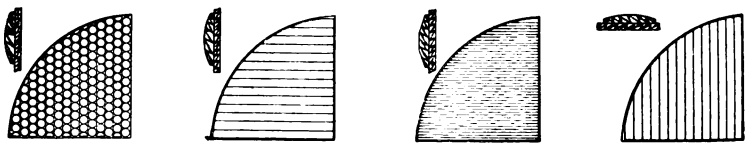
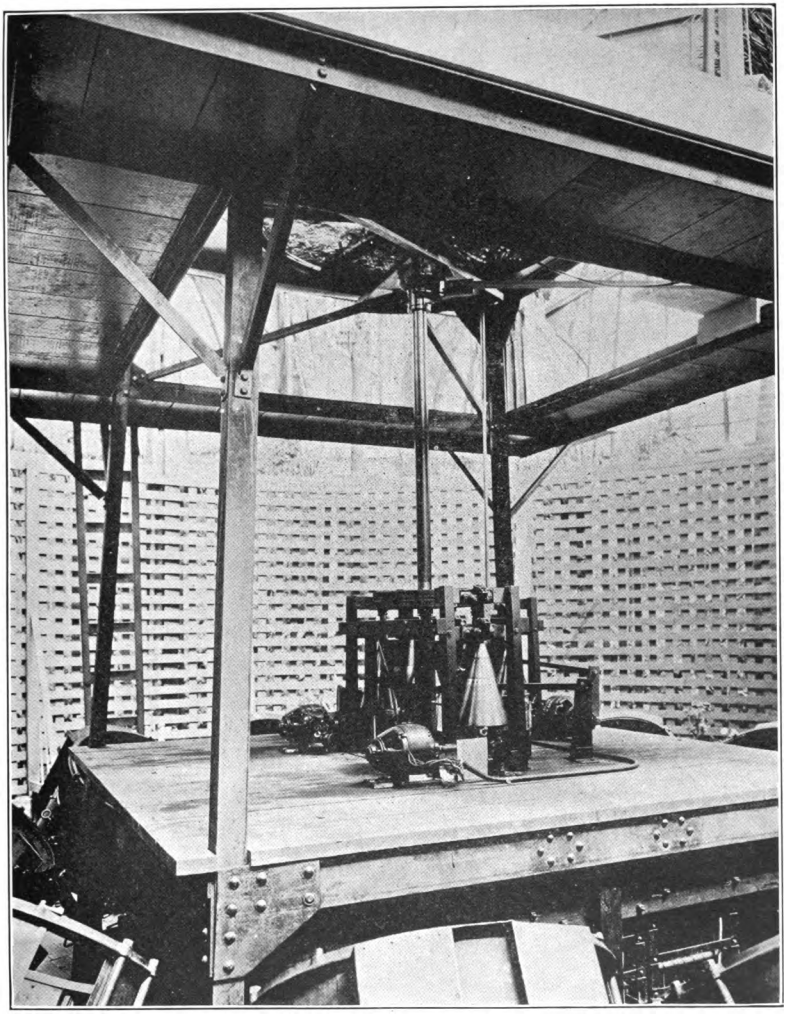


FIG. 13—LENS QUADRANTS FOR ELECTRIC KALEIDOSCOPE—PALACE OF HORTICULTURE

common practise of distributing lights generally over the skylight, which produces strong specular reflection and also gives the greatest illumination on the floor in the center of the room, where it is least desired.

Digitized by Google



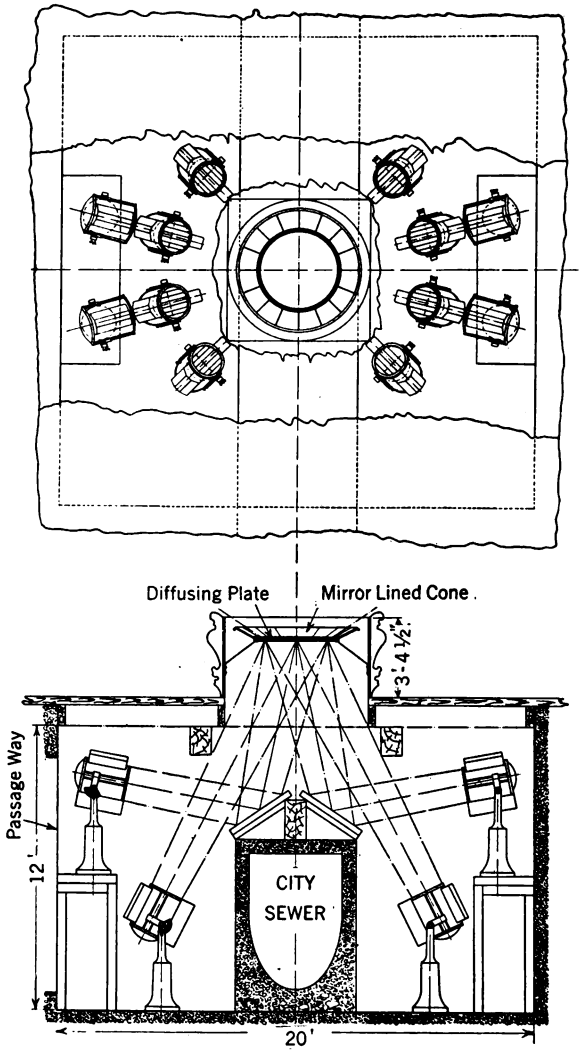
[RYAN]

FIG. 12—ELECTRIC COLOR KALEIDOSCOPE, PALACE OF HORTICULTURE

Digitized by Google

Digitized by Google

High Bay Lighting. For the illumination of high bays, large units, singly or in pairs, were placed at the maximum height in special reflectors (Fig. 17), designed to prevent waste illumi-



FIGS. 14 AND 15—PLAN OF INDIRECT LIGHTING—FESTIVAL HALL

nation on vertical surfaces and obtain maximum intensity on the floor with relatively uniform distribution, and absence of spots. The main buildings of the Exposition were lighted in this way, using only one-tenth watt per square foot with the mazda

Digitized by Google

B lamps, resulting in approximately one-half foot-candle average illumination for lamp heights, in some cases over 100 ft. (30.5 m.) above the floor. This illumination was primarily for janitor and police service, exhibitors being required to furnish their own lighting.

"Life Within" Effects. At previous expositions the windows were dark at night, producing a gloomy effect. In addition to lighting up the general architecture with proper relative values of illumination, lights were placed behind the windows which had been glazed with diffusing glassware, having a good daylight

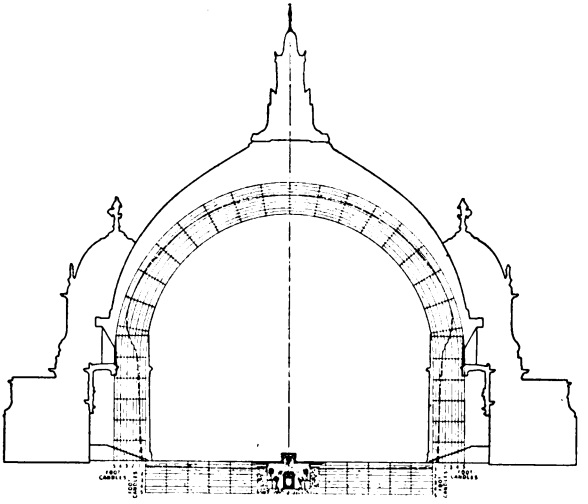


FIG. 16—INTERIOR SURFACE ILLUMINATION—FESTIVAL HALL

texture. In some cases, for the introduction of color, the diffusion was increased by painting the glass. The general effect at night was of festivity, of "life within", which added animation to the general charm of the Exposition, particularly when viewed from an elevation.

Lamps for window lighting ranged in size from 60 to 250 watts, depending upon the size of the window to be lighted. The clerestory windows which were unpainted, were lighted by 150-watt lamps dipped in orange lacquer. Practically all of the entrance windows were painted, and these were illuminated by clear lamps in sheet tin extensive reflectors. All of the window lights, with the exception of those in the domes, were suspended on drop cords. The dome windows were lighted by 250-watt

Digitized by Google

lamps in angle reflectors mounted five feet to the rear of the windows.

Combination Fountain and Light Sources. The original fountains of the Rising and Setting Sun, in the Court of the Universe, designed by McKim, Mead and White, were 65 ft. (20 m.) high. In order to accommodate the lighting the architects increased the height to approximately 95 ft. (29 m.) and constructed them as shown in Fig. 18. The flutes of the 31-ft. (9.4-m.) section beginning at a point 37 ft. (11.3 m.) above the ground surface, were made of ¼-in. (6.35-mm.) thick special diffusing glass, backed up by a secondary sheet of sand-blasted glass to eliminate structural shadows. By arranging 96 1500-watt mazda lamps in twelve rows of eight each, this section of the fountain became an immense candle or light source at night. To dissipate the

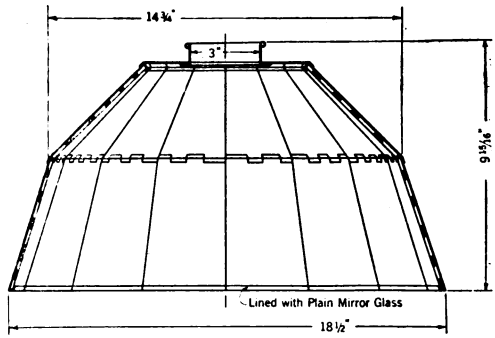


FIG. 17—HIGH BAY REFLECTOR

heat generated by this bank of lamps, consuming 144 kw., a 5-h.p. blower was installed in the base of each fountain and created a forced cooling draft which was discharged from air vents at the base of the ball surmounting the shaft. This ball was lighted from the inside by eight 250-watt mazda lamps. Notwithstanding the fact that the 96 lamps in each one of these fountains had a combined initial spherical candle power of approximately one quarter of a million, the intrinsic brilliancy was relatively low and did not cause disagreeable eye strain. The horizontal and vertical surfaces illuminated by the two fountains were approximately one-half million square feet (46,450 sq. m.).

To carry out the night effect of these fountains, the figure surmounting the glass ball was lighted by two 6-volt, 108-watt incandescent spot-lights located on the roofs of the adjoining

Digitized by Google

buildings. The sculptured friezes above the two basins were lighted by twenty-four 150-watt lamps in weatherproof solid body angular reflectors submerged in each basin (Fig. 19). The isolux chart in Fig. 20 shows the initial calculated values for the Court of the Universe and the North Approach. The isolux curves shown in the court proper were calculated from the

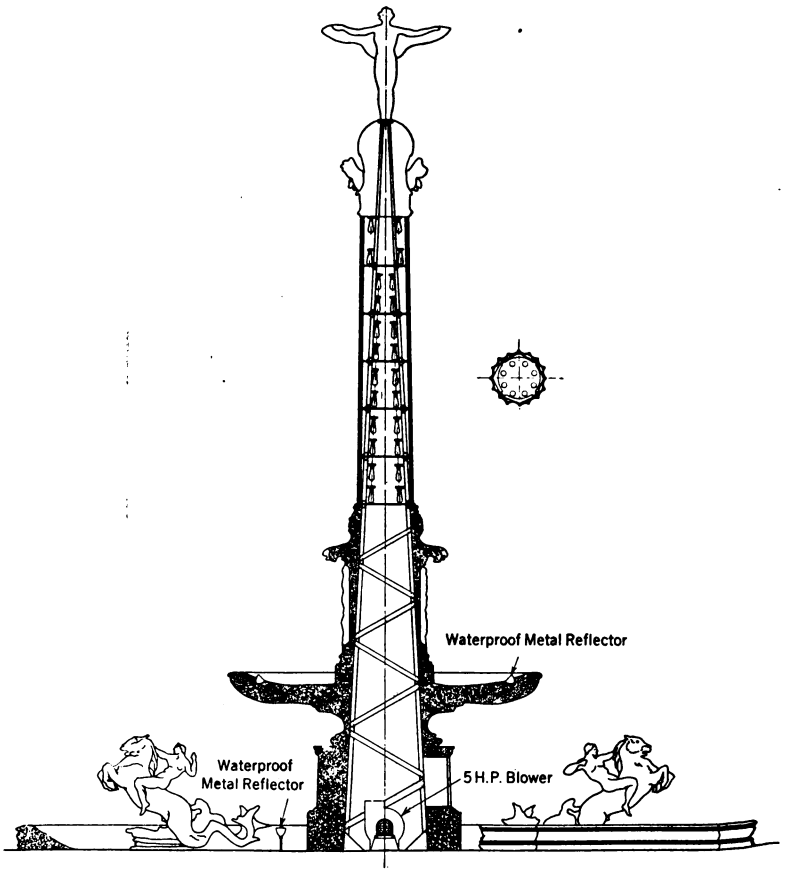


FIG. 18—ELEVATION OF FOUNTAIN IN THE COURT OF THE UNIVERSE

initial candle power values of the 1500-watt lamps in the fountains. Subsequently, for economic reasons, the illumination was reduced by lowering the voltage on the lamps in order to lengthen their life. The approach to this court was lighted by sixteen 1500-watt lamps, installed in a shell design type of standard. These standards were located on the balustrade

Digitized by Google

surrounding the central pool and flood-lighted the building facade, the promenade receiving most of the light by reflection from the large columns and the overhanging cornice.

Relief Wall Lighting by Concealed Sources. The practise of past expositions has been to place exposed lamps on the rear of the columns to light the back walls. This resulted in lines of light being visible from almost any point of view, which detracted from the appearance of the columns.

In the lighting of the colonnades in the Court of the Universe and the Court of the Four Seasons, three column cups were sunk into the central flute in the rear of each column, in the case of

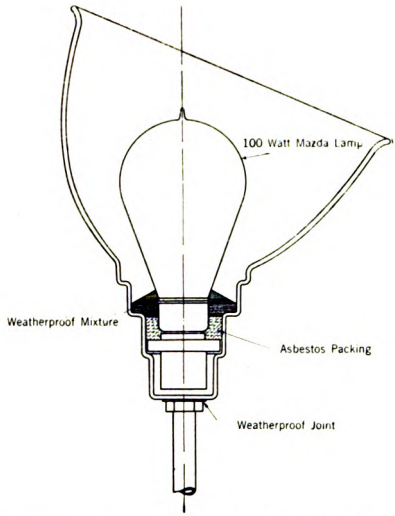


FIG. 19—CROSS SECTION OF ANGULAR WEATHER-PROOFED REFLECTOR

the former, and on the center line of the plain columns in the latter case. These column cups were of pressed opal glass and embedded in the columns (Fig. 21) and spaced 10, 22 and 34 ft. (3.05, 6.7 and 10.4 m.), respectively, above the floor level of the colonnade. Fig. 22 shows the distribution characteristics of this type of cup with a 150-watt clear mazda lamp. The walls were illuminated with a rising light resulting in a total absence of specular reflection and an average illumination on the wall surface of approximately 4 foot-candles. The illumination curve (Fig. 23) shows the values obtained on a vertical line directly back of one of the columns and curve *a-a*, Fig. 20, shows the calculated illumination on a horizontal line along the wall

Digitized by Google

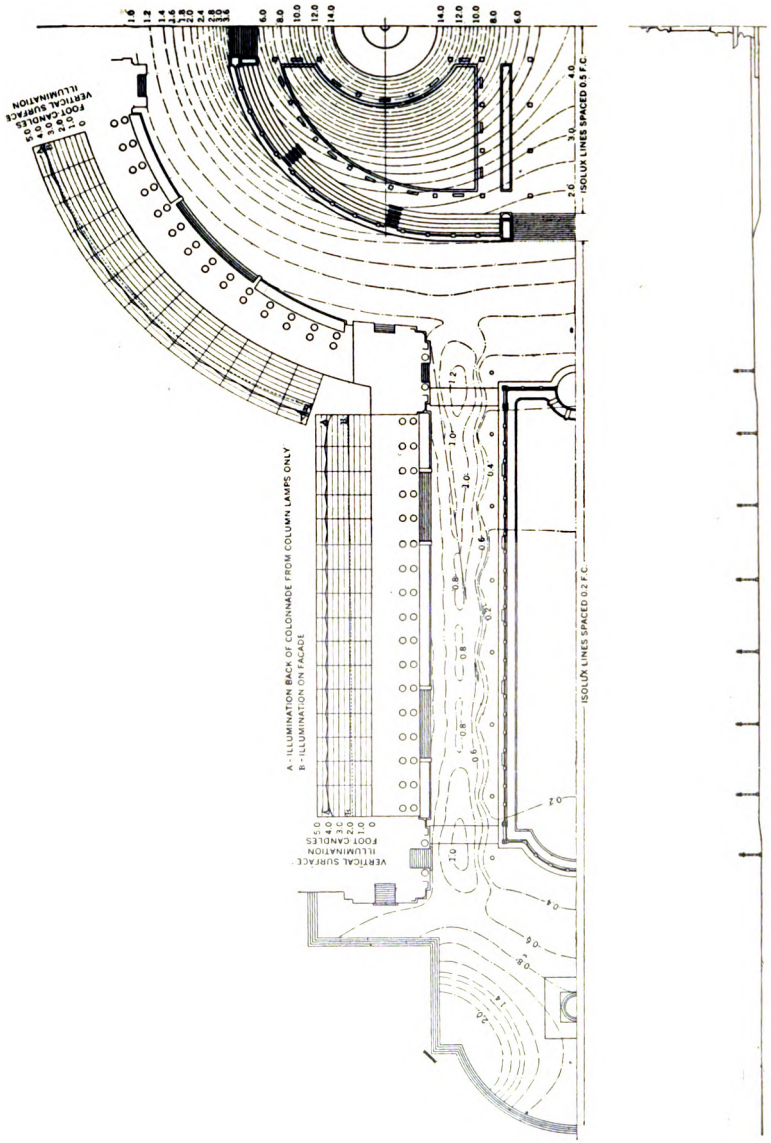

ISOLUX LINES SPACED 0.5 F.C.
ISOLUX LINES SPACED 0.2 F.C.
A - ILLUMINATION BACK OF COLONNADE FROM COLUMN LAMPS ONLY
B - ILLUMINATION ON FAÇADE
VERTICAL SURFACE ILLUMINATION FOOT CANDLES

FIG. 20—ISOLUX AND ILLUMINATION DIAGRAM—COURT OF THE UNIVERSE AND NORTH APPROACH

Digitized by Google

surface 6 ft. (183 cm.) above the floor level. While the column cups were invisible from any part of the court proper, when viewed from the rear of the colonnade they appeared like great drops of molten metal, producing an unusual effect.

The Creation of Mystery in the Lighting of Open Courts. In designing the Court of Abundance, the architect wished to impress as far as possible a feeling of mystery, or something carrying the mind down through the ages. This effect was strengthened

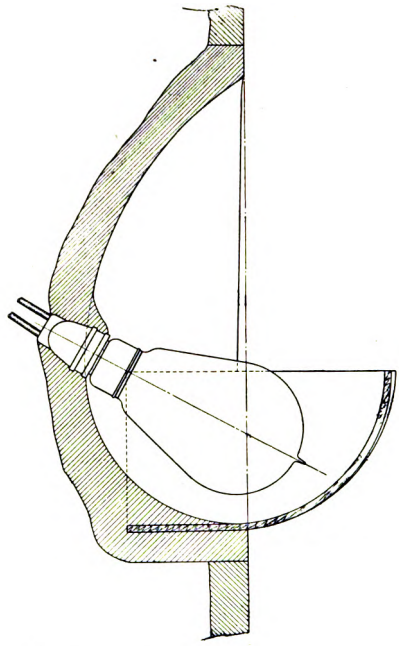


FIG. 21—CROSS SECTION OF COLUMN CUP

by a harmonious blending of illumination by searchlights, incandescent lights, gas flambeaux and illuminated steam.

The general illumination of this court came from three sources: the snow crystal standards, the cloister lanterns and the gas flambeaux. The snow crystal standard, or as it was sometimes called, the "sunburst" (because of the design suggestion), contained over 600 15-watt round globe orange-dipped incandescent lamps. There were two of these standards in the main court and four in the north approach to this court. On either side and at the spring line of each cloister arch there was suspended a

Digitized by Google

Gothic lantern with orange glass panels. In addition to lighting the cloister and the adjacent gardens these lanterns were especially valuable for their decorativeness. The gas flambeaux were formed by four rising serpents hissing fire into a flaming caldron. There were six of these located in the court proper and sixteen in the north approach to the court.

The additional "effect" lighting came from the boiling steam-electric caldrons flanking the east and west entrances, the steam-electric torches of the organ tower, the flood and relief lighting of this tower and the illuminated steam issuing from the ball of the central fountain. The steam used in producing these effects

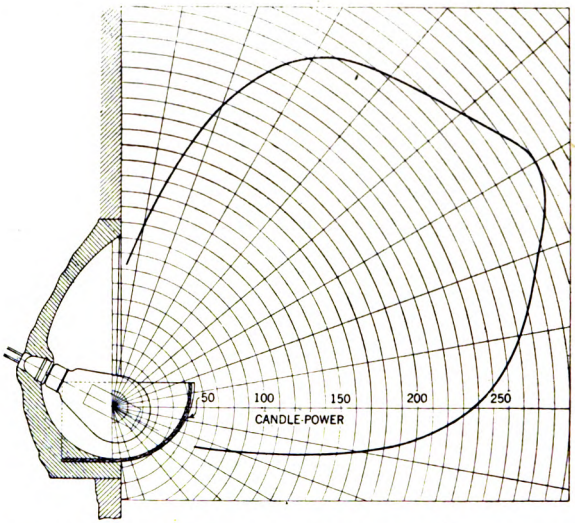


FIG. 22—CANDLE-POWER DISTRIBUTION OF 150-WATT MAZDA LAMP IN COLUMN CUP

was delivered by a 15-h.p. gas-fired boiler located in the base of the organ tower. The color tone of the court at night ranged from orange to rose red.

Flood and Relief Lighting to Obtain Artistic Reflections. In order to create reflections of unusual beauty, especially in the illumination of the Palace of Fine Arts, banks of searchlights with diverging doors of varying degrees, designed to meet the requirements, were used to flood-light the building, producing what might popularly be called "triple moonlight". This was supplemented by concealed yellow incandescent light in the soffits of the cornices to the rear of the columns, thereby providing three effects: flood lighting, relief lighting, or the com-

Digitized by Google

bination of both. Variety was obtained for special occasions by the introduction of color into the searchlight beams.

Concealed Cascade Lighting. In the lighting of cascades at previous expositions, either the source has been visible, or a reflection of the source, which is equally undesirable. The cascades in the Court of the Four Seasons were so illuminated that neither the light sources nor their images in the water were visible. By the use of green light on the rear surface and red and orange on the front, the effect of iridescence was produced.

Preservation of Curvature and Detail in Relief. The preservation of the curvature and detail in relief was accomplished by lights

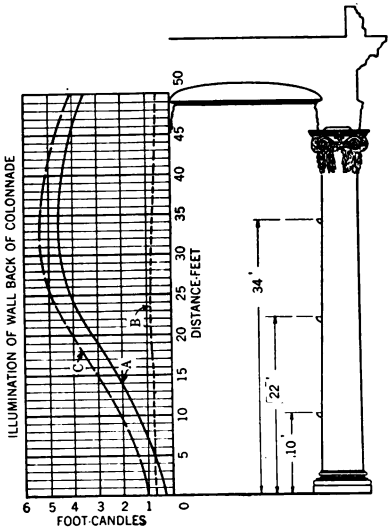


FIG. 23—COURT OF FOUR SEASONS—COLONNADE WALL ILLUMINATION
A—150-watt Mazda lamps in column cups. *B*—2-light luminous arc banner standards. *C*—Column cups and banner standards.

of different strengths and colors thrown from different or opposite directions on the same object. For example, to preserve the curvature of the walls and the relief of the figures in the four season niches of the Court of Four Seasons, 50 100-watt mazda lamps ranging from red to canary, in metal reflectors, were installed on the top rear side of the niche colonnade (Fig. 24).

The main arches throughout the Exposition were lighted with concealed red light on one side and pale lemon yellow on the other. All of the lamps used in any one arch were of the same initial candle power, but, due to the difference in absorption of the two colors, the light from one side was of much greater intensity than from the other, thereby preserving the curvature and depth in relief.

Digitized by Google

Changeability of Lighting Effects. Three-hundred and seventy-three arc searchlights, ranging in size from 13 to 36 in. (33 to 91.4 cm.), were used throughout the Exposition, and 450 concentrated-filament mazda searchlights, forming a so-called "mosquito fleet", were also employed. By the use of colored gelatine screens, it was an easy matter on short notice to change the entire aspect of the Exposition by coloring the lights on the flags, towers and buildings (flooded with searchlights) as well as the rays of the scintillator. For instance, on the 17th of March, the Exposition, including the canopy above, was illumined in green tones; on Orange Day, orange prevailed; on the "Nine Years After" anniversary of the burning of San Francisco, red was the predominating color; and on Santa Clara Day, red and

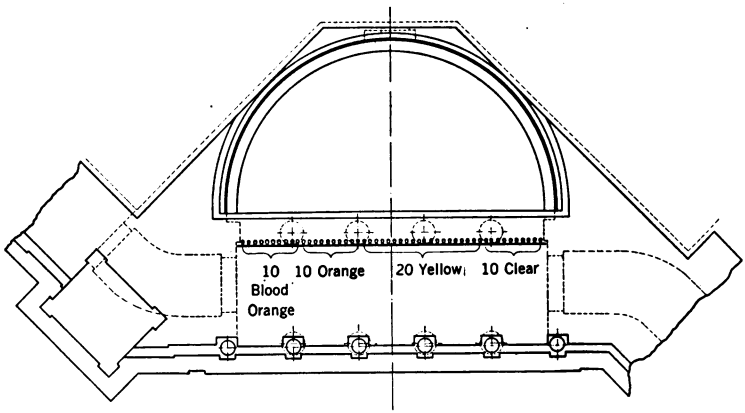


FIG. 24—SEASON NICHE LIGHTING—COURT OF FOUR SEASONS

white, the colors of the university, were used—thereby making it possible for the first time to introduce considerable variety on short notice, and at nominal expense, into the illumination effects of an international exposition.

In conclusion, the lighting consisted primarily of direct, masked, concealed and projected effects, created by a harmonious blending of luminous arcs, searchlights, mazda lamps and gas lights.

The high-current luminous arc lamp was selected for general flood lighting of the facades, lawns and shrubbery, on account of the white quality, high efficiency and relatively low maintenance cost where great quantities of light were required.

The searchlights were used for illuminating towers and mina-

Digitized by Google

rets, flags and other features where concentration and high intensity were necessary.

Mazda lamps, in all sizes from 10 to 1500 watts, were employed

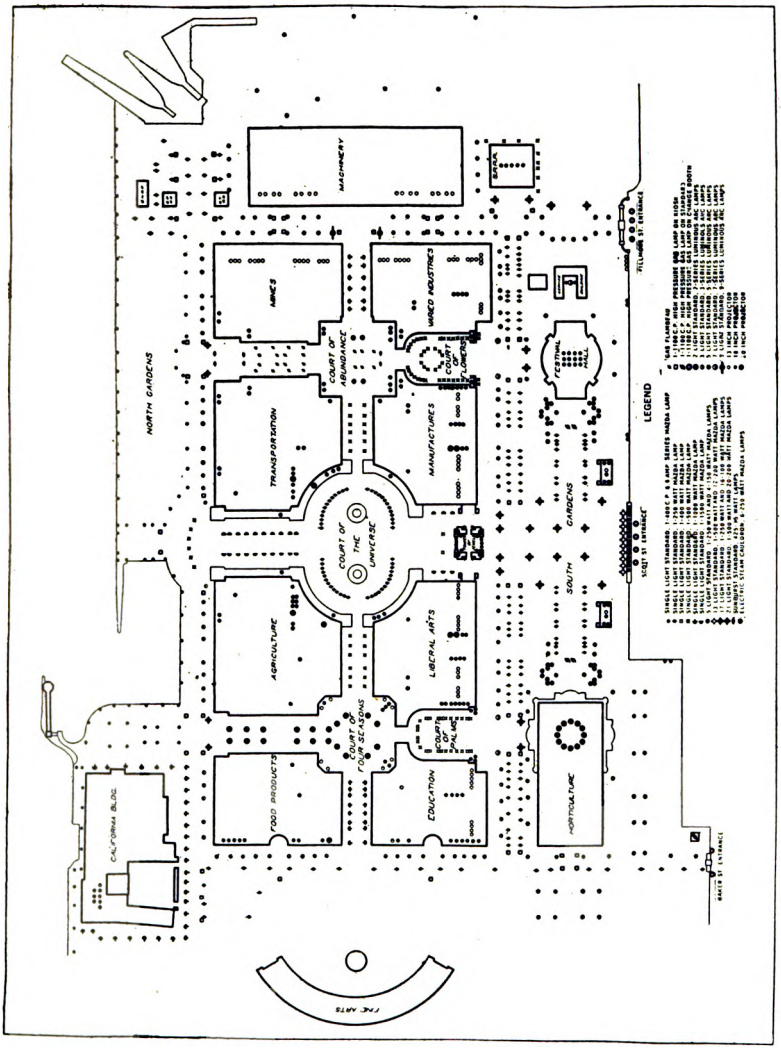


FIG. 25—GROUND AND BUILDING PLAN OF MAIN EXHIBIT PALACES
Showing Location of Incandescent and Arc Standards, Gas Emergency Lights and Searchlights

generally throughout the Exposition, especially where space was limited, where warm, normal tones were required and flexibility was of fundamental importance.

High-pressure gas lighting played an important part in street

Digitized by Google

lighting in the Foreign and State sections, low-pressure gas for emergency purposes, and gas flambeaux for special effects.

The unusual consideration given to esthetics and the suppression of high intrinsic brilliancy effects, naturally introduced certain features in the lighting which, from a purely engineering point of view, would be regarded as inefficient. Taken as a whole from the point of effects obtained, initial cost, maintenance and general efficiency, it was broadly conceded that the illumination of the Panama-Pacific International Exposition surpassed that of all previous expositions.

GENERAL LIGHTING AND POWER DATA

PANAMA-PACIFIC INTERNATIONAL EXPOSITION—1915

		Total kw.
Incandescents installed and operated by Exposition Co. (approx.)		3650
Luminous Arcs " " " " " "		548
Searchlights " " " " " "		1792
Pumps " " " " " "		750
Total Power and Light " " " " "		6740
State and Foreign Buildings	Light inside	716
" " " "	Light outside	134
" " " "	Power	75
Total Power and Light—States and Foreign Sites		925
ZONE	Light inside	1352
	Light outside	676
	Power	875
Total Power and Light—Zone		2903
EXHIBITORS	D-C. Light	45
	D-C. Power	618
	A-C. Light	1293
	A-C. Power	1430
Total Power and Light—Exhibitors		3386
Total Connected Load at Exposition		13954
Peak Load, occurred February 20th, 7:45 p. m.		8200
Average Peak		7880

INSTALLED AND OPERATED BY EXPOSITION COMPANY

	Number
Mazda incandescent outlets (approx.)	35000
Mazda incandescent standards	588
6.6-ampere ornamental luminous arcs	800
Luminous arc standards	208
High-pressure gas "arcs"	275
" " " " (standards)	205
Low-pressure gas lamps	232
Searchlights (100 13-in.; 200 18-in.; 25 30-in.; 48 36-in.)	373
Total pieces of illuminating glassware (approx.)	5000

Digitized by Google

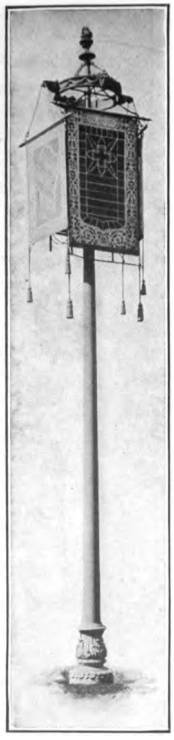


FIG. 26—FRONT VIEW OF FIVE AND SEVEN-LIGHT LUMINOUS ARC LAMP BANNER STANDARD —HEIGHT 35 FEET

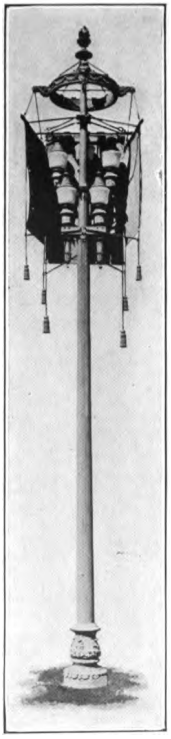


FIG. 27—REAR VIEW OF FIVE-LIGHT LUMINOUS ARC LAMP BANNER STANDARD, HEIGHT, 35 FEET

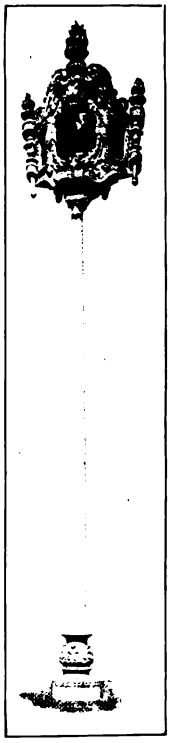


FIG. 28—THREE-LIGHT LUMINOUS ARC LAMP CARTOUCHE STANDARD, HEIGHT 35 FEET

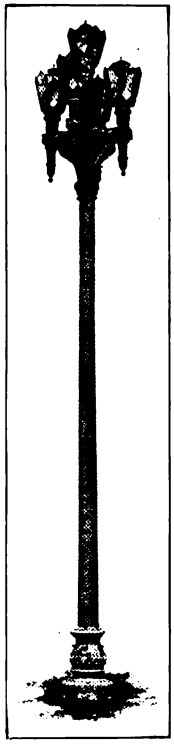


FIG. 29—FIVE LIGHT LUMINOUS ARC LAMP BAND CONCOURSE STANDARD, HEIGHT 35 FEET

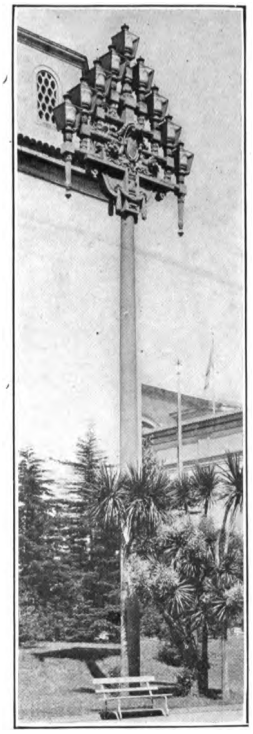
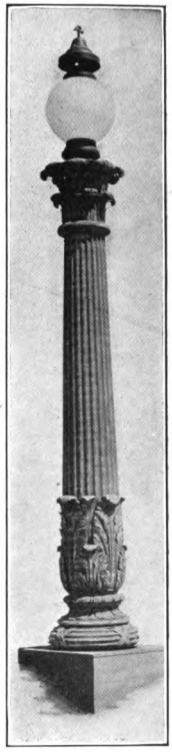


FIG. 30—NINE-LIGHT LUMINOUS ARC STANDARD, HEIGHT 35 FEET



[RYAN]

FIG. 31—MARINA TYPE PENN GLOBE HIGH PRESSURE GAS ARC STANDARD

Digitized by Google

Digitized by Google

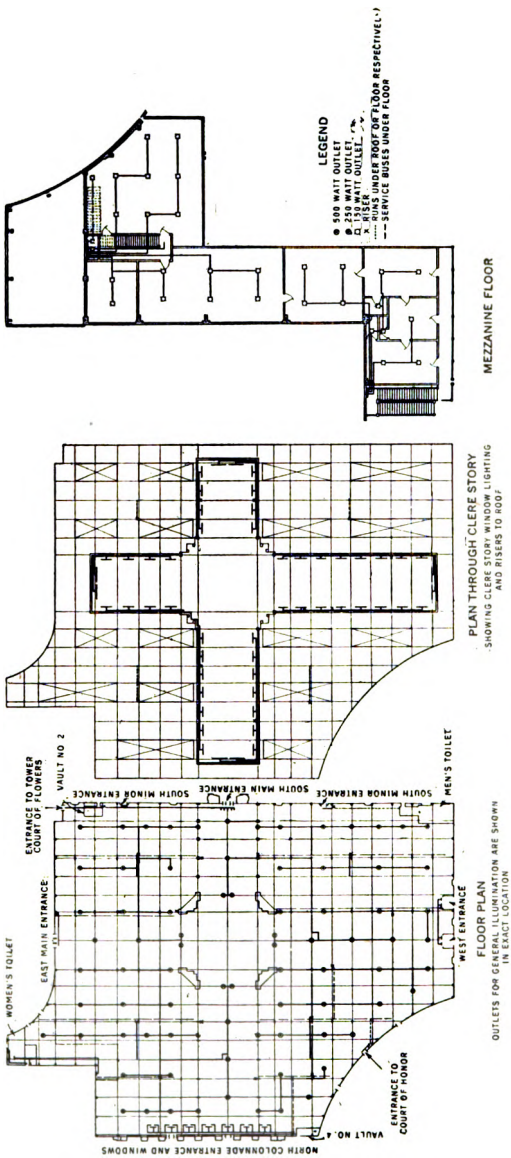


FIG. 32—OUTLET AND WIRING DIAGRAM—PALACE OF MANUFACTURES

Digitized by Google

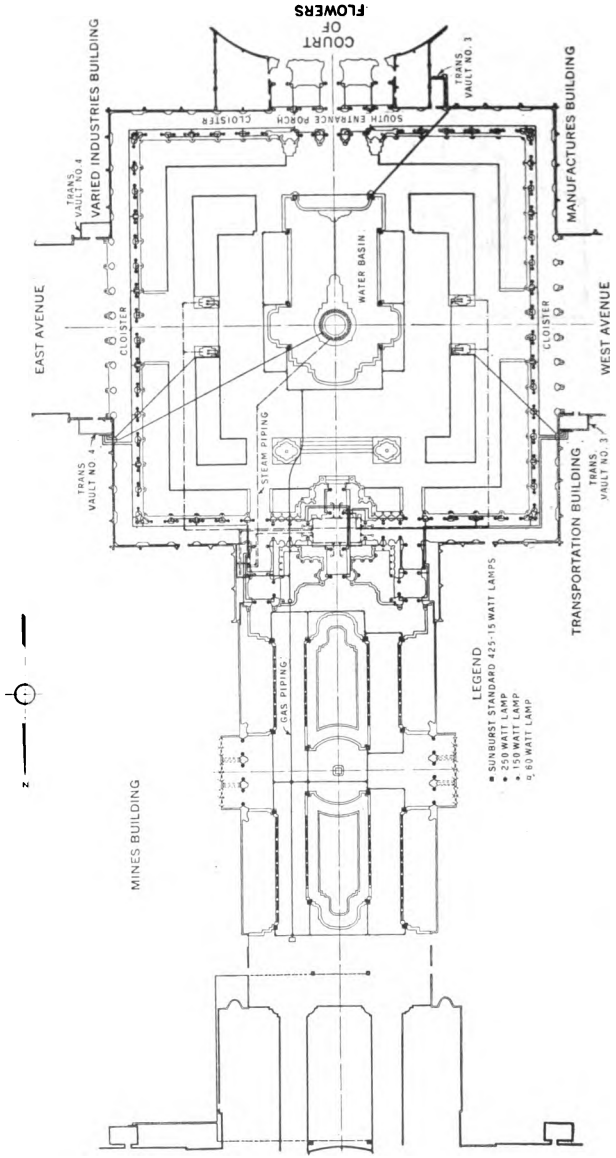
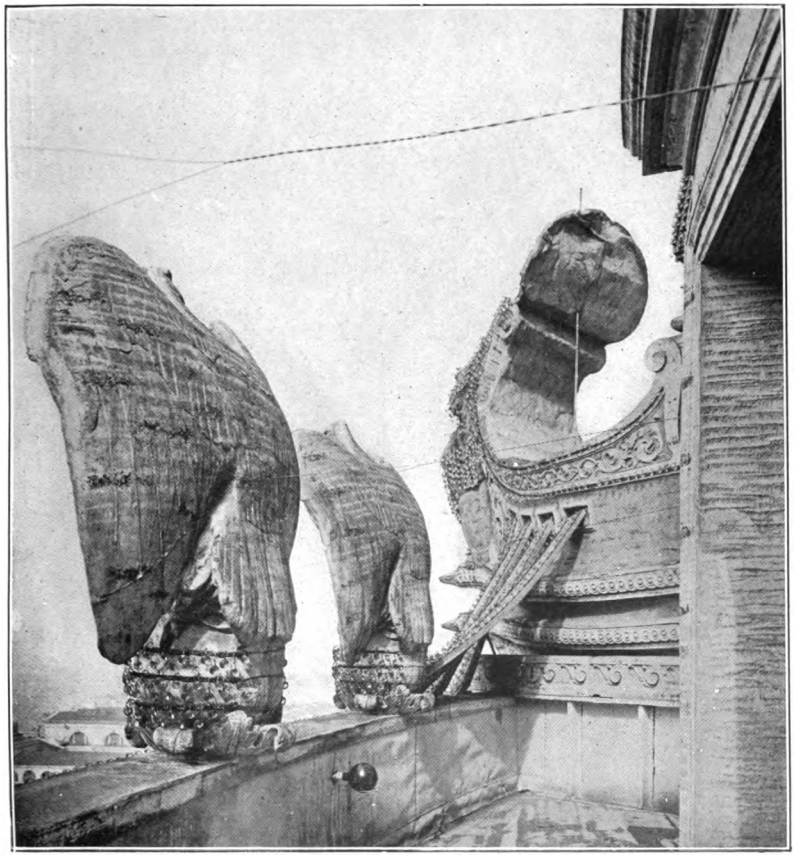


FIG. 33—OUTLET, WIRING, STEAM AND GAS DIAGRAM—COURT OF ABUNDANCE

Digitized by Google



[RYAN]

FIG. 34—VIEW OF TOWER OF JEWELS SHOWING METHOD OF SUSPENDING JEWELS AND RED LAMP FOR RELIEF LIGHTING

Digitized by Google

Digitized by Google

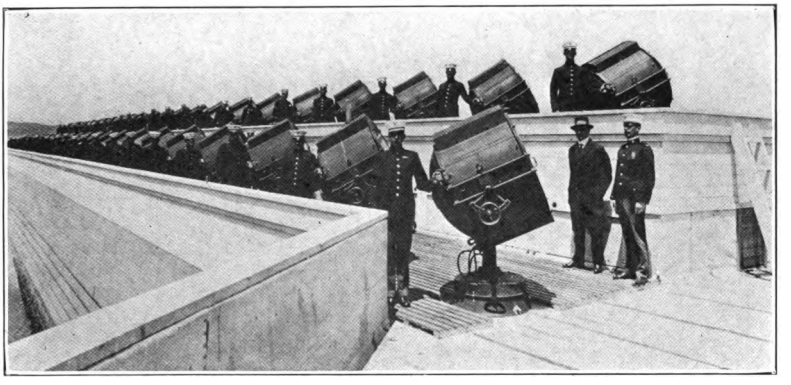
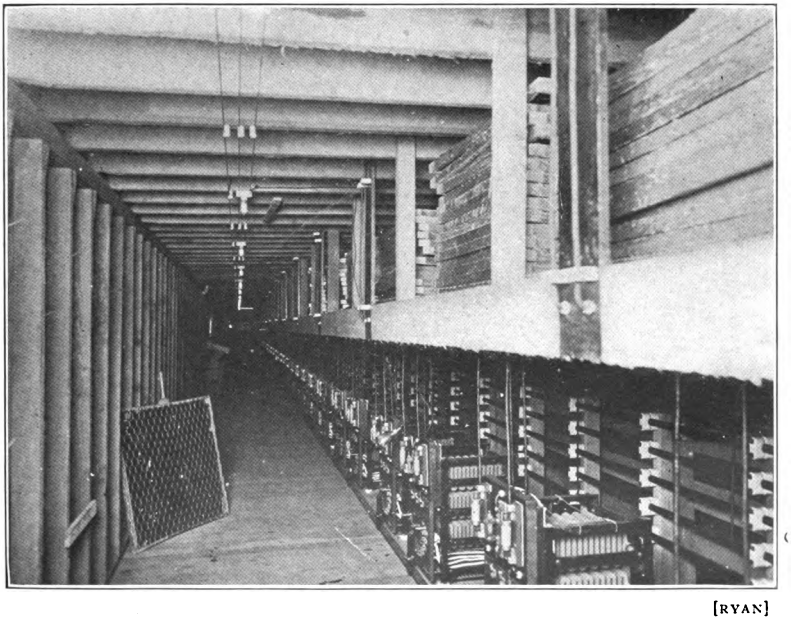


FIG. 35—ELECTRIC—COLOR—STEAM—SCINTILLATOR



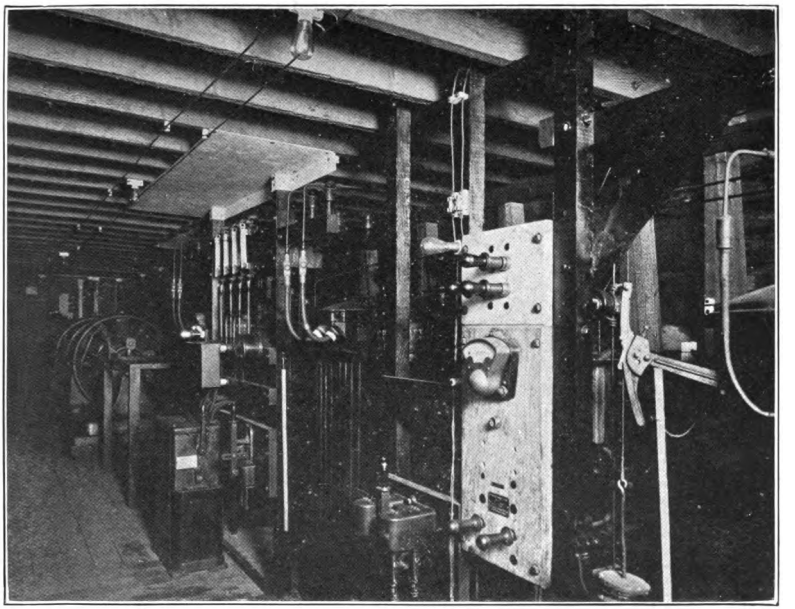
[RYAN]

FIG. 36—INTERIOR VIEW OF SCINTILLATOR PIER

This shows color screens resistances and distribution circuits.

Digitized by Google

Digitized by Google



[RYAN]

FIG. 37—INTERIOR VIEW OF SCINTILLATOR PIER

This shows motor-generator set with station apparatus.

Digitized by Google

Digitized by Google

Fig. 38—Panoramic View from Fillmore Hill

Digitized by Google

Fig. 38 Panoramic View from Fairmont Hill

Digitized by Google

Digitized by Google

Digitized by Google

Fig. 39—Street Lighting—States and Foreign Sites

Approximately four miles of streets in this section were illuminated by 205 Penn Globe ornamental high pressure gas arcs

Digitized by Google

Digitized by Google

A. XXX. 11.A.1
A. L. E. F.
Dat. XXX. Jan.

Fig. 89. Street Traffic Signals and Pedestrian Safety

Side Entrance Pedestrian Subway

Pedestrians may cross at this point only when signal indicates safety

Pedestrians must use subway to avoid traffic

Digitized by Google

Digitized by Google

Fig. 40—Night View West Entrance to Zone

In addition to the concessionaires' usual outline lighting, the exposition company maintained a combination system consisting of five-light Humphrey gas arcs in ornamental lanterns and in pairs tied together by an arch of Mazda lamps with star-shaped triple reflectors supporting red ribbon festoons.

Digitized by Google

Fig. 40—Night View West Entrance to Zone

In addition to the concessionaires' usual outline lighting, the exposition company maintained a combination system consisting of five-light ornamental lanterns and in pairs tied together by an arch of Mazda lamps with star-shaped triple reflectors supporting red ribbon festoons.

Digitized by Google

Digitized by Google

Digitized by Google

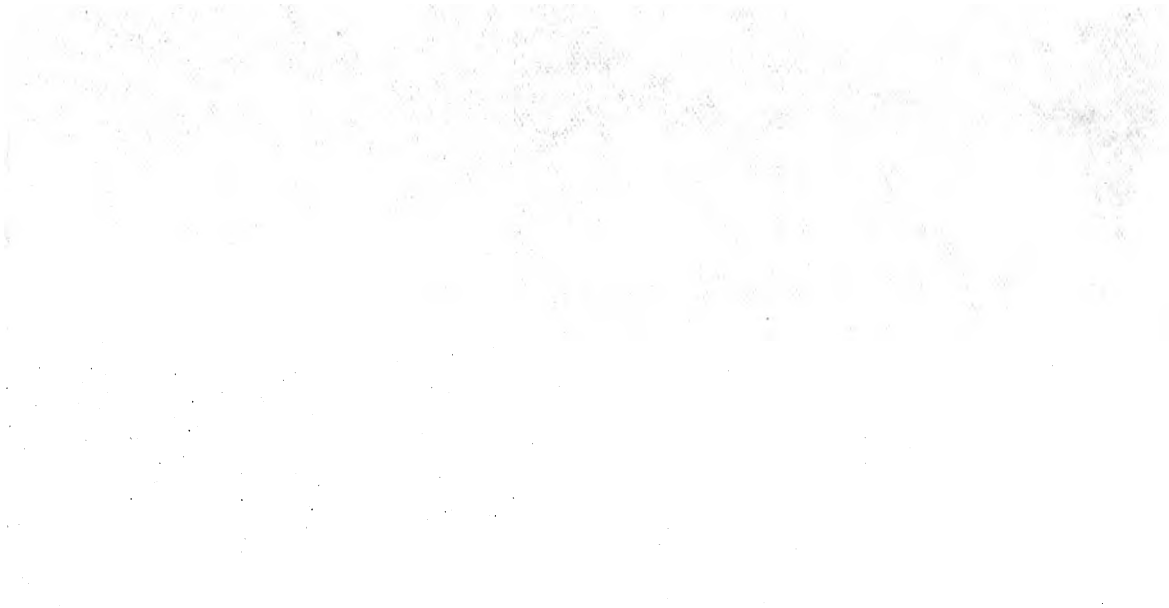


Fig. 41—Twilight View from Festival Hall

This shows the towers bathed in red relief lighting before the flood lighting was turned on—It also shows the line of five-light 6.6-ampere luminous arc banner standards

Digitized by Google

Fig. 11.—Twin 7,500-kilowatt Generator from Test Floor.

The rotating field is supported on the floor by a ring girder, which is shown in the background. The stationary armature is supported on a bedplate and can be moved laterally on rails to uncover the rotating field for inspection.

Digitized by Google

Digitized by Google

Digitized by Google

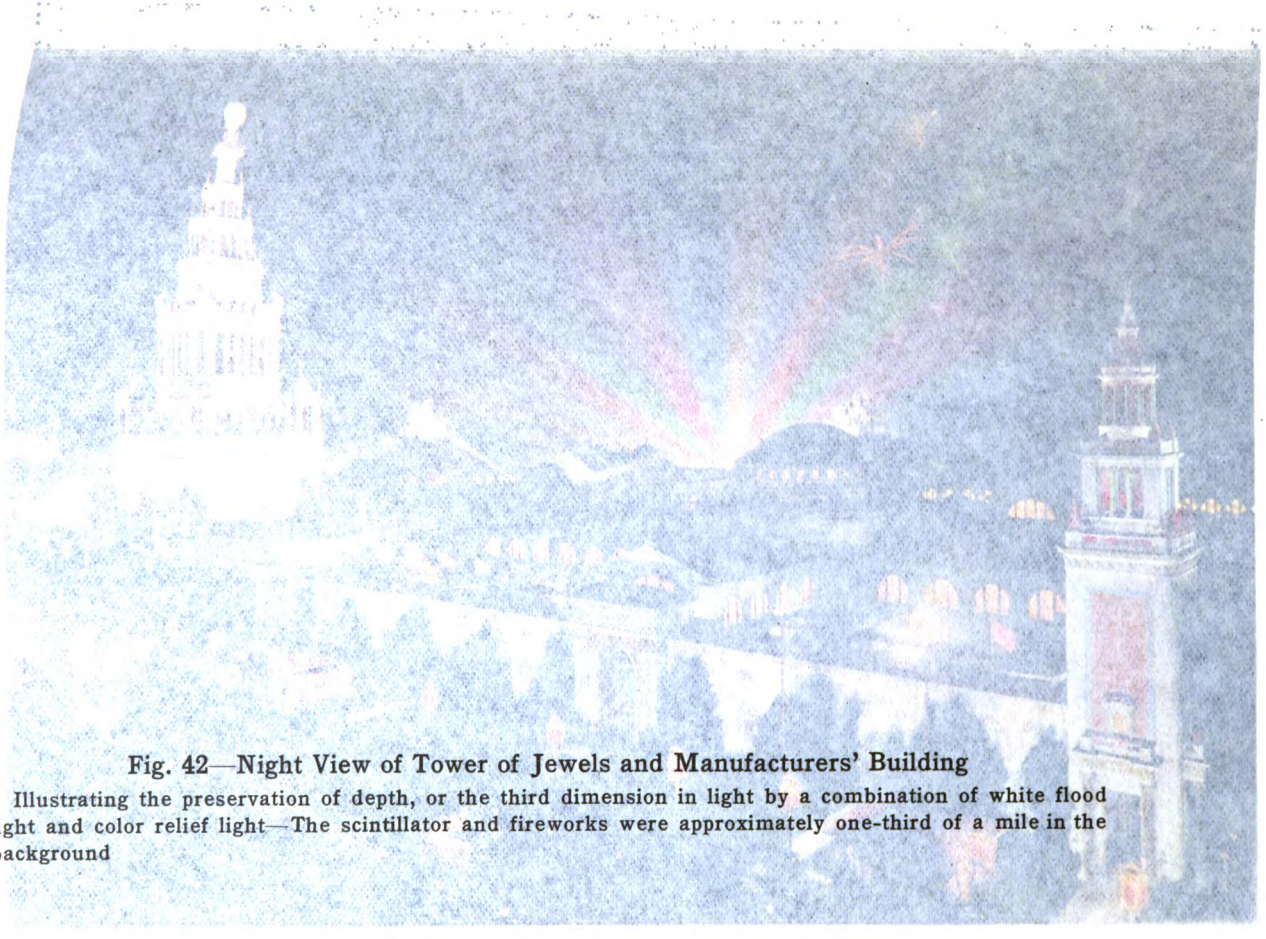


Fig. 42—Night View of Tower of Jewels and Manufacturers' Building

Illustrating the preservation of depth, or the third dimension in light by a combination of white flood light and color relief light—The scintillator and fireworks were approximately one-third of a mile in the background

Digitized by Google

Fig. 42.—Night View of Tower of Jewels and Manufacturers' Building

Illustrating the preservation of depth, or the third dimension in light by a combination of white flood light and color veiled light.—The scintillator and fireworks were approximately one-third of a mile in the background.

Digitized by Google

Digitized by Google

Digitized by Google

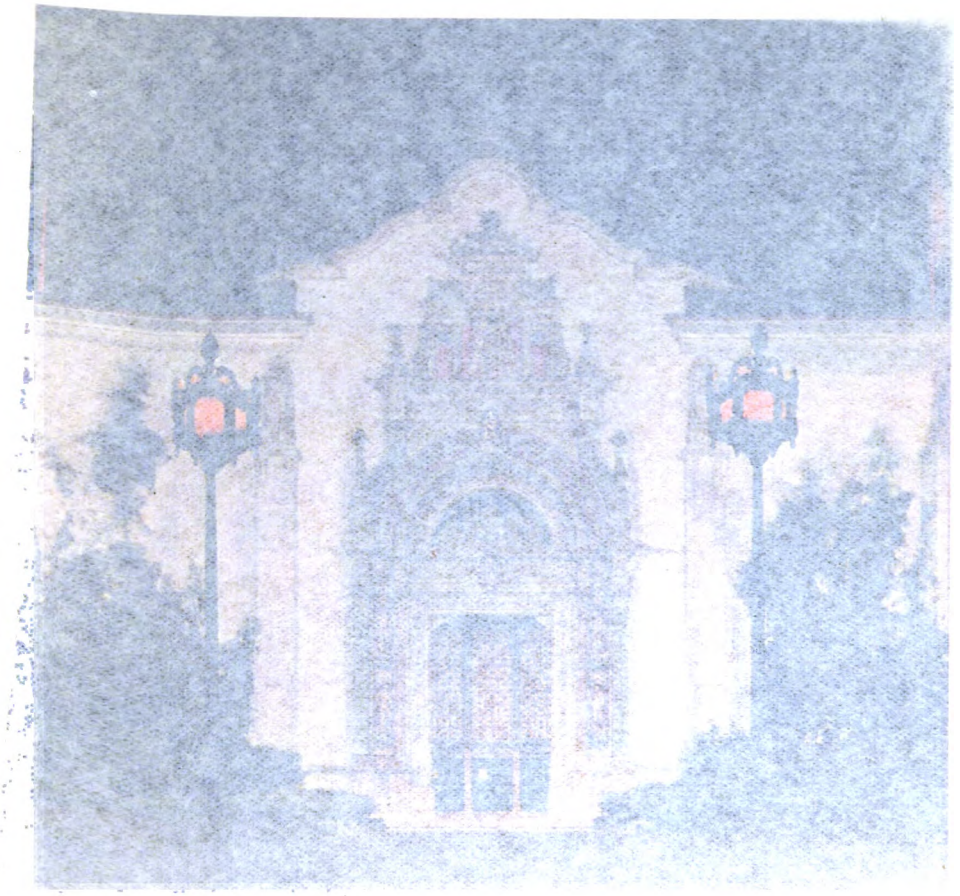


Fig. 43—South Portal—Palace of Industries

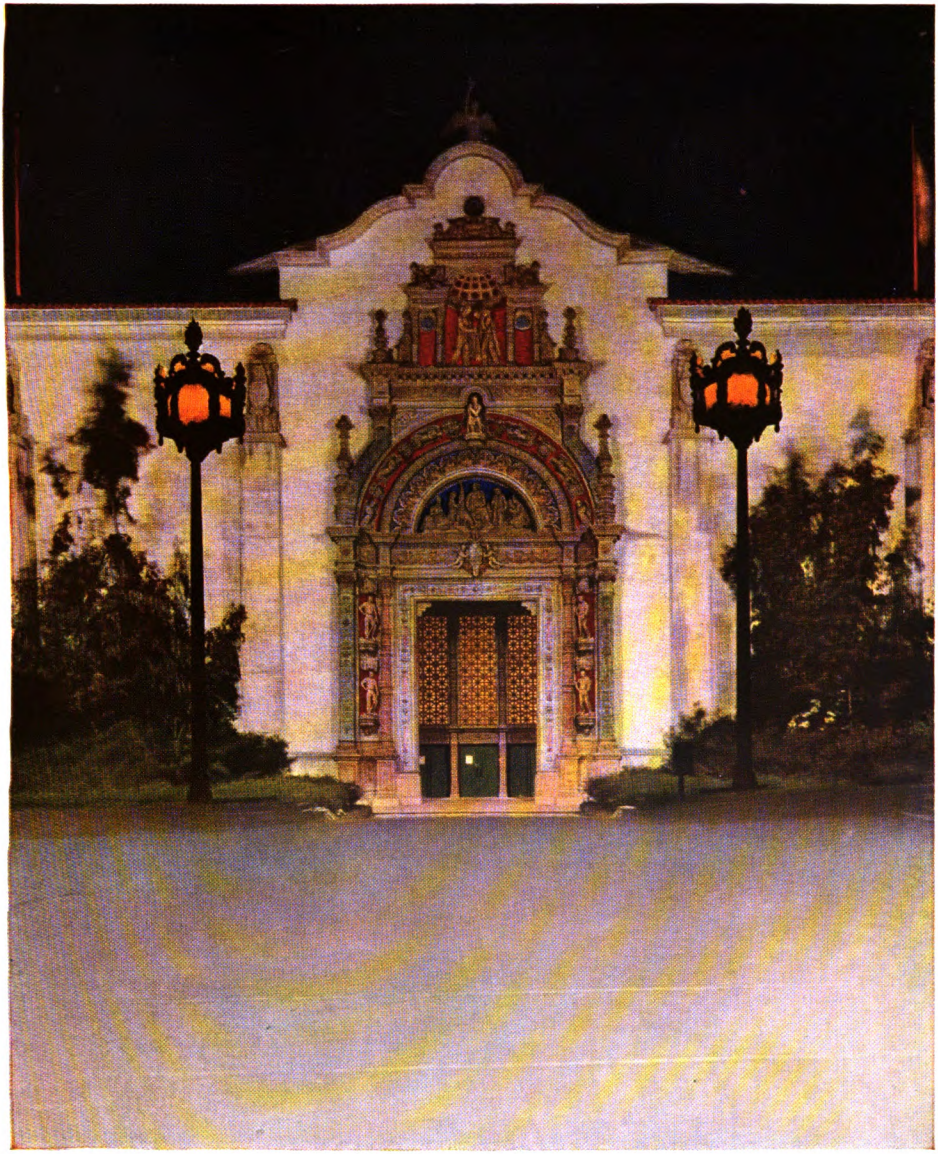
Showing three-light, 35-foot Cartouche standards—This illustrates excellent depth of detail with normal shadows

Digitized by Google

Fig. 43—South Portal—Palace of Industries

Showing three-light, 36-foot Cartouche standards. This illustrates excellent depth of detail with normal shadows

Digitized by Google



Digitized by Google

Digitized by Google

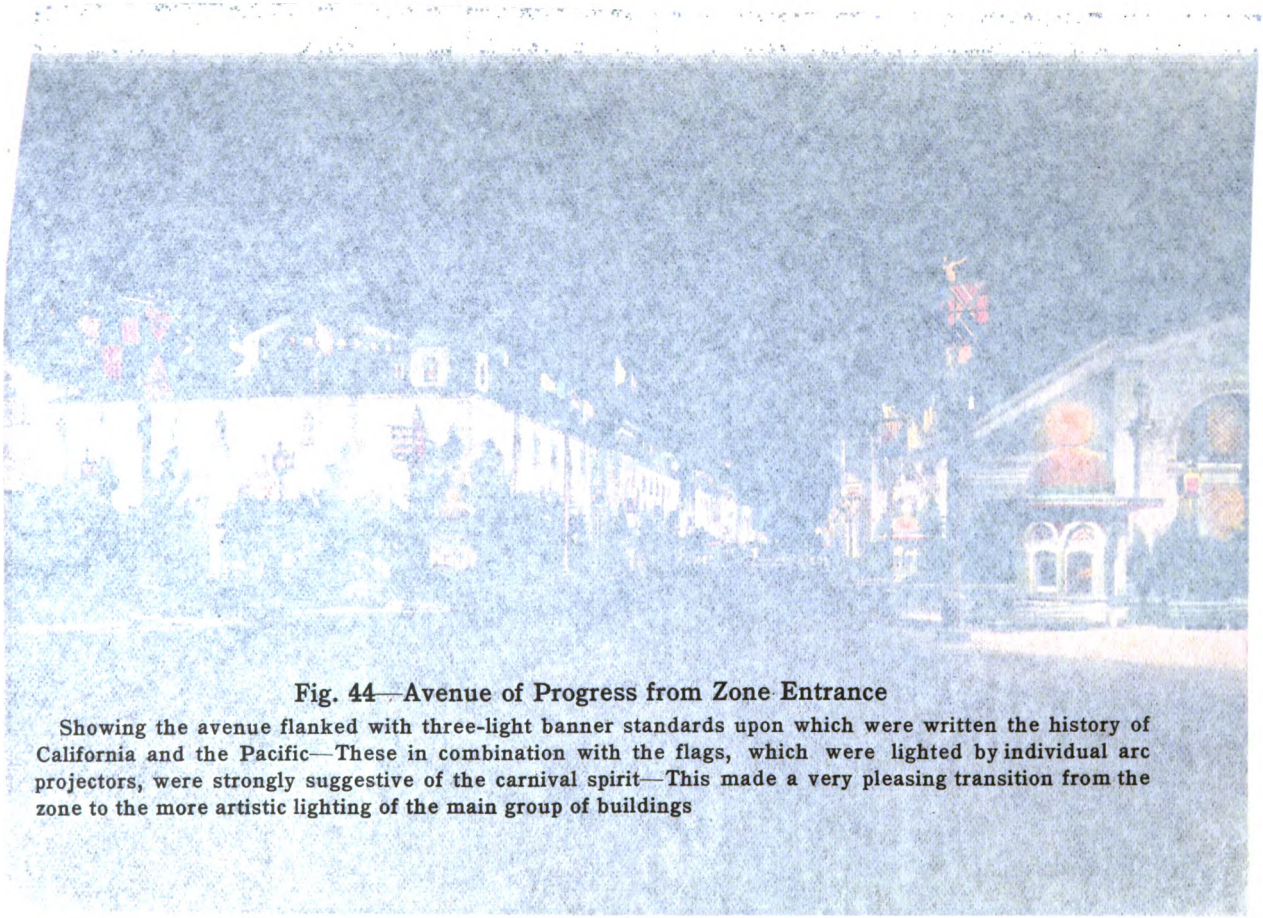


Fig. 44—Avenue of Progress from Zone Entrance

Showing the avenue flanked with three-light banner standards upon which were written the history of California and the Pacific—These in combination with the flags, which were lighted by individual arc projectors, were strongly suggestive of the carnival spirit—This made a very pleasing transition from the zone to the more artistic lighting of the main group of buildings

Digitized by Google

Fig. 44.—AVENUE TO PROPOSED TOWN ENTRANCE.

Showing the avenue with broad tree-lined planting strip between standard upon which were placed lights, which are combination with the Pacific—This was a very pleasing transition from the California and the Pacific—This was a very pleasing transition from the photoplasm, were strongly suggestive of the curving lavishing spirit—This was a made by individual lighted by individual are to one of the most attractive illuminations ever equipped by the main thoroughfare to

Digitized by Google

Digitized by Google

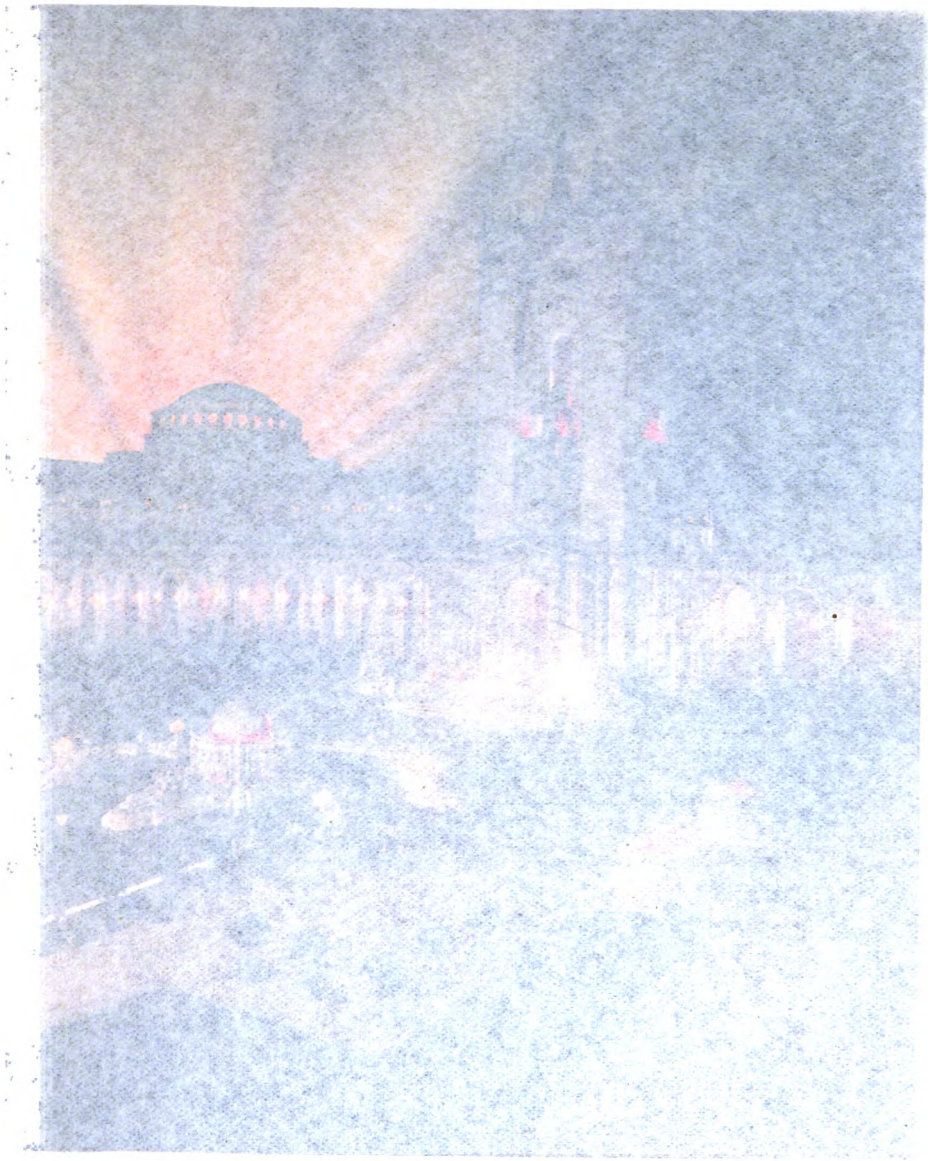


Fig. 45—A Section of Court of Abundance

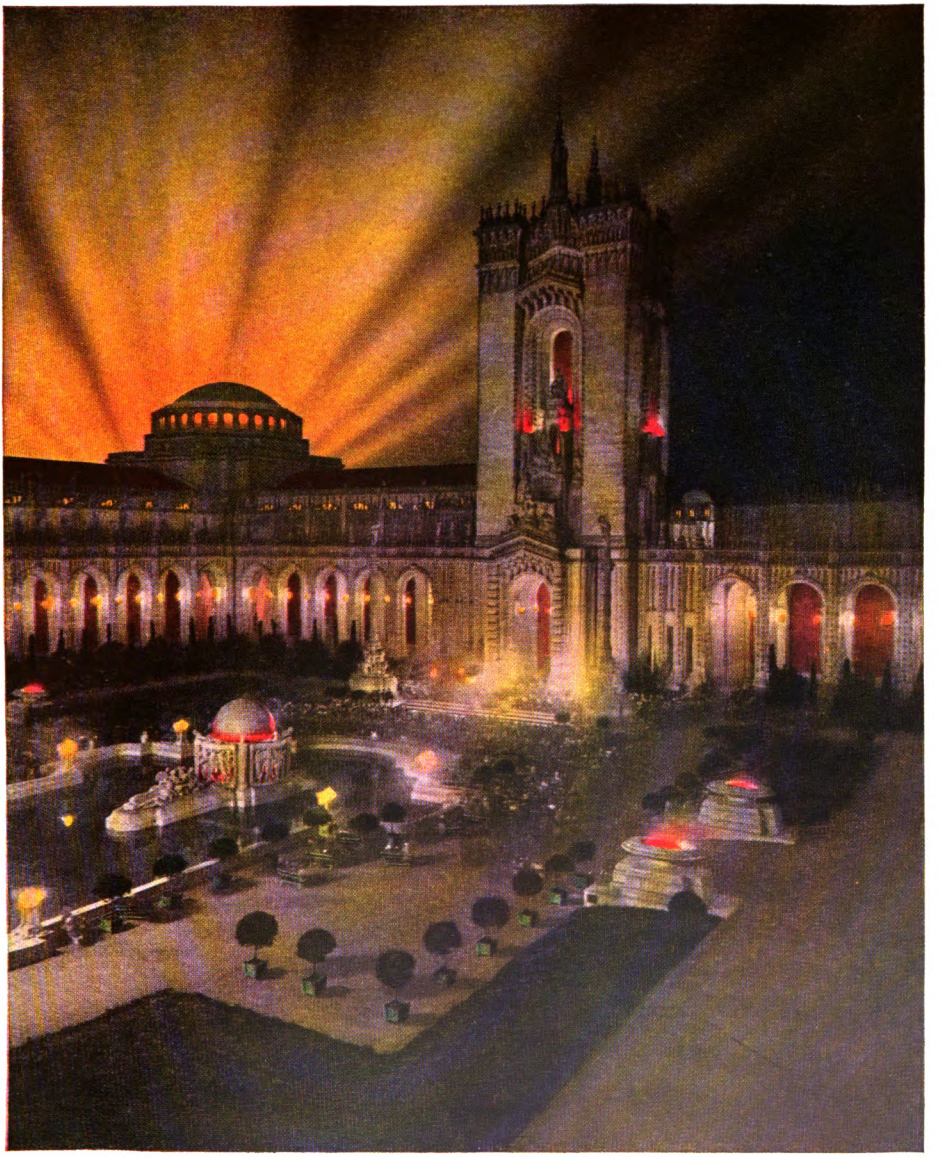
Showing the organ tower and Aitken fountain, with steam caldrons and fiery serpent flambeaux—In addition to the happy effect of the orange colored cloister lanterns, the flaring gas and ruby steam caldrons and torches on the tower did much to heighten the feeling of mystery in this Court at night.

Digitized by Google

Fig. 45—A Section of Court of Abundance

Showing the organ tower and Aitken fountain, with steam caldrons and fiery serpent flambeaux—In addition to the happy effect of the orange colored cloister lanterns, the flaring gas and ruby steam caldrons and torches on the tower did much to heighten the feeling of mystery in this Court at night.

Digitized by Google



Digitized by Google

Digitized by Google

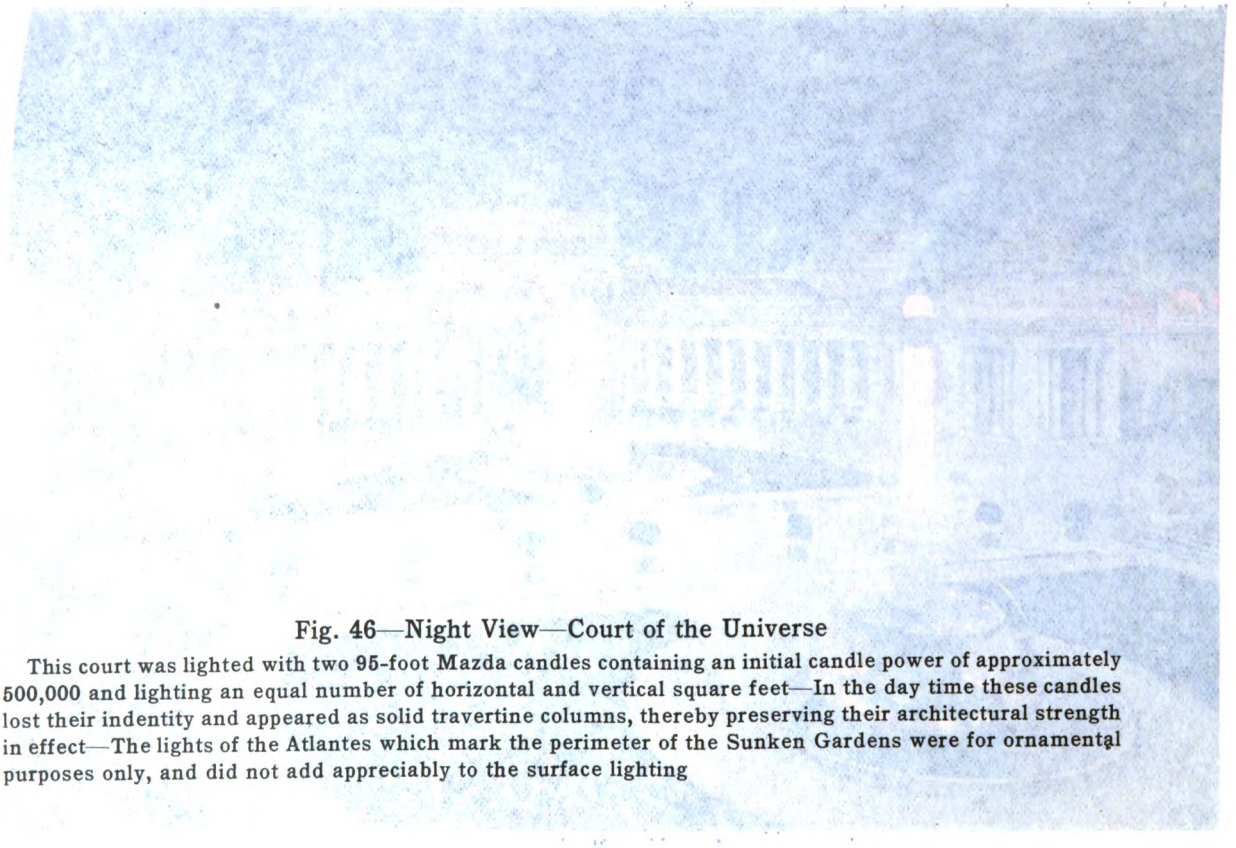


Fig. 46—Night View—Court of the Universe

This court was lighted with two 95-foot Mazda candles containing an initial candle power of approximately 500,000 and lighting an equal number of horizontal and vertical square feet—In the day time these candles lost their indentity and appeared as solid travertine columns, thereby preserving their architectural strength in effect—The lights of the Atlantes which mark the perimeter of the Sunken Gardens were for ornamental purposes only, and did not add appreciably to the surface lighting

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

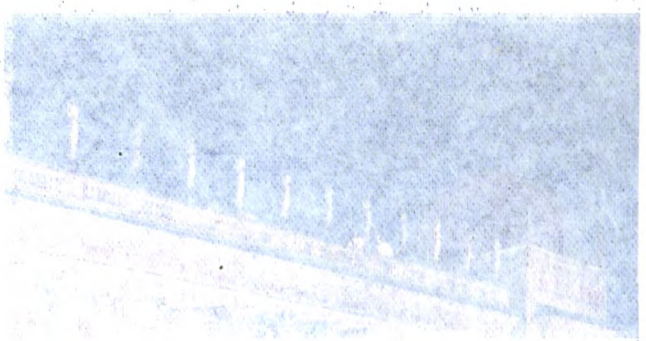


Fig. 47—North Approach to the Court of the Universe

Illustrating in silhouette the shell-type 1500-watt Mazda standards mounted on the balustrade for facade illumination—It also shows the seraphic jewel figures which were cross lighted each with individual incandescent searchlights placed behind the balustrades of the opposite facade—It will be observed that the flood lighting sources, as well as the lamps for illuminating the rear walls, were completely screened so that the architecture stands out free from interference of exposed sources

PLATE XLII.
A. I. E. E.
VOL. XXXVI, 1917.

Digitized by Google

Fig. 47. Nautilus Pompilius, to the Count of the Limestone.

Digitized by Google

Digitized by Google

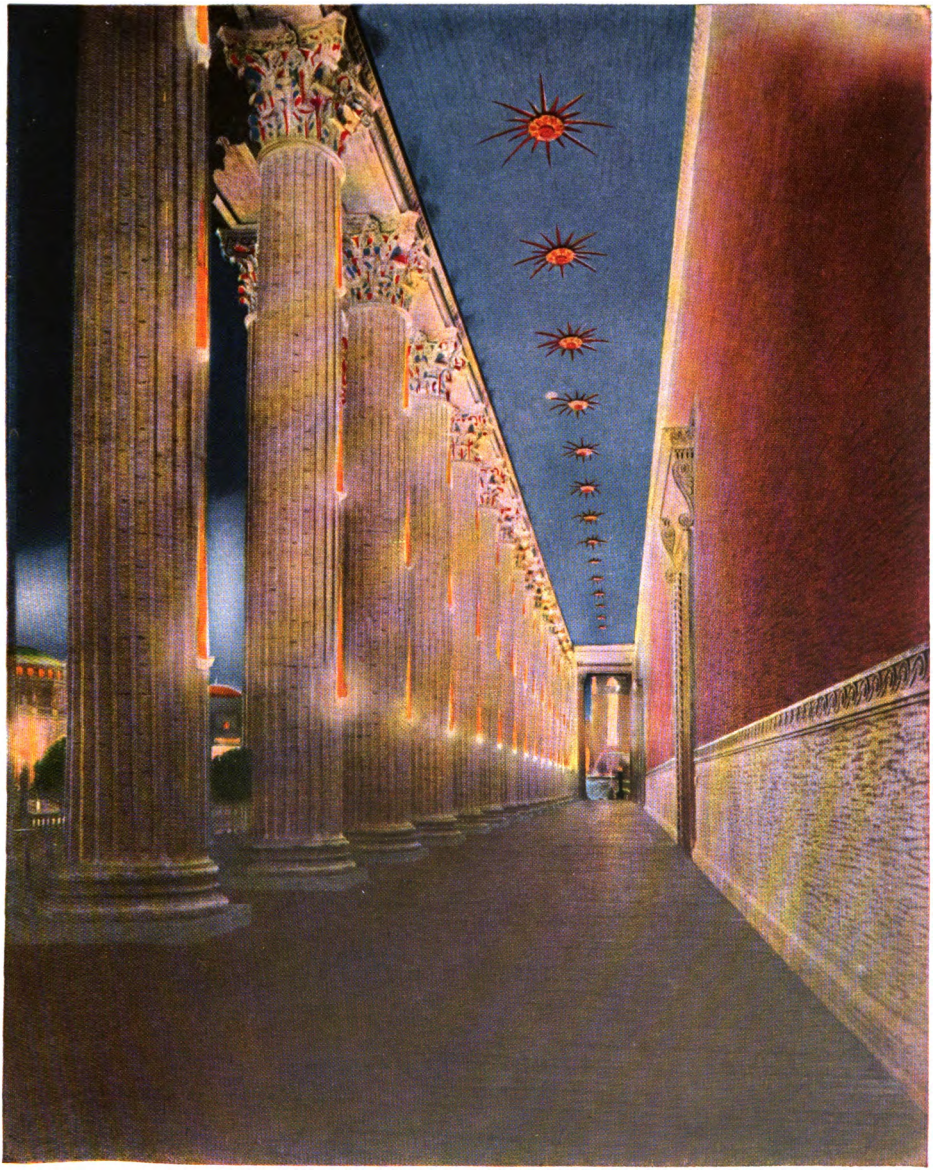
Digitized by Google

Fig. 48—Cusp Column Lights—Colonnade—Court of Universe

These lights were used for illuminating the walls and ceiling at the rear of the colonnade and they incidentally suggested a rain of fire—This method made it possible to obtain the illumination without having the source exposed to view at any position in the main court

Digitized by Google

Digitized by Google



Digitized by Google

Digitized by Google

Fig. 49—Colonnade Approach to the Court of Four Seasons

This view illustrates the complete concealment of column cusps for the wall lighting and also it shows the two-light luminous arc banner standards used for facade lighting—This was the only arc lighted court of the Exposition

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

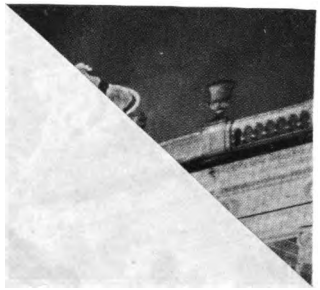


Fig. 50—Court of Four Seasons—Looking North

The circular lagoon surrounded by the dark green masses furnished some of the most beautiful reflections at the Exposition

Digitized by Google

Fig. 20.—Coast to Fort Sesostris.—Looking North.

The extinct volcano in the background is seen to the right of the high grey mass with flattened top and from its position is probably intrusive.

Digitized by Google

Digitized by Google

Fig. 51—West Arcade Entrance—Court of Four asons

This illustrates the uniformity of illumination of the facade and shows the nda of the Palace of Fine Arts in the distance

Digitized by Google

Fig. 91.—West Arcade Entrance—Court of Four Lions

This illustrates the uniformity of illumination of the facade and shows the Palace of Fine Arts in the distance

Digitized by Google

Digitized by Google

Digitized by Google

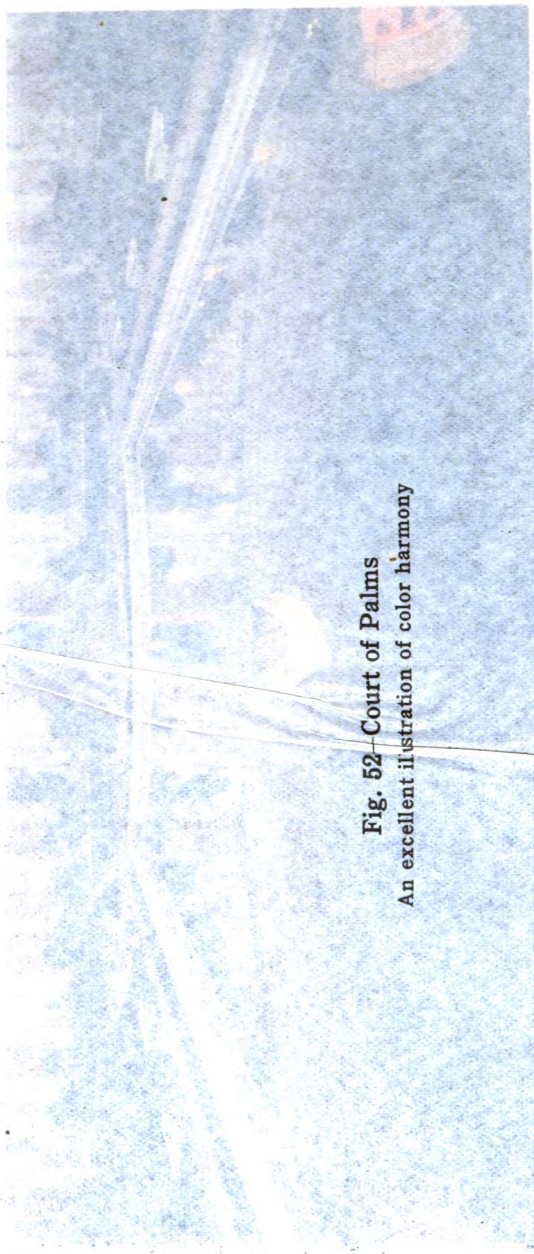


Fig. 52—Court of Palms
An excellent illustration of color harmony

Digitized by Google

Fig. 23.—Coat of Arms

An excellent illustration to color harmony

Digitized by Google

Digitized by Google

Digitized by Google

Fig. 53—Reflection in West Lagoon—South Gardens

This shows the Horticulture Building in the foreground, and the towers of the Court of Palms

Digitized by Google

Fig. 23. Kaghaghat in motorgaon West Lagaon - Shoot through Garo Hills showing the Building in the foreground and the tower of the Count of Psalms

Digitized by Google

Digitized by Google

Digitized by Google

Fig. 54—Reflection in East Lagoon—South Gardens
Festival Hall on the right and the towers at the approach to the Court of Flowers at the left

Digitized by Google

Fig. 64. Reflection in East Lagoon, South Castalia.

Legend: Here is shown the path of the rays of light from the Comet to Earth as seen at the telescope

Digitized by Google

Digitized by Google

Digitized by Google

Fig. 55—Tower of Jewels

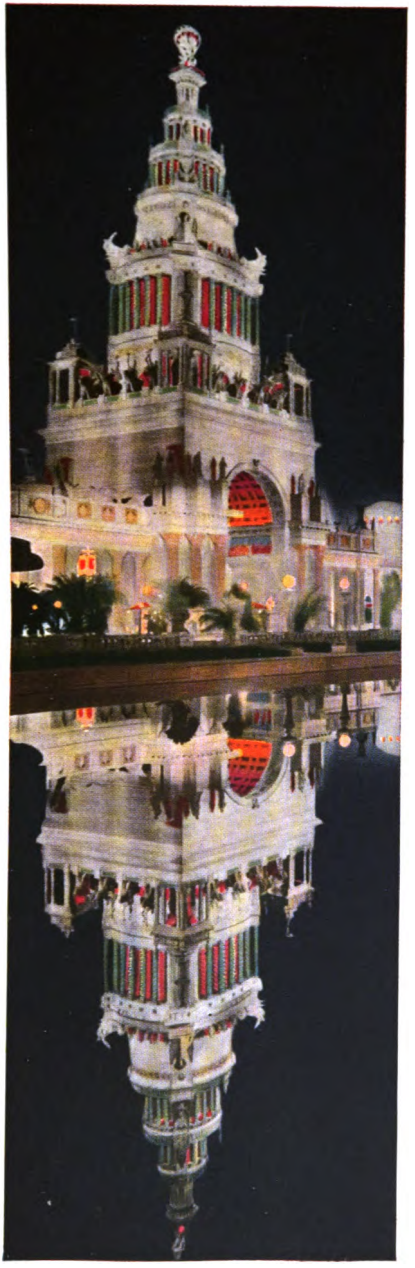
This tower was 435 feet high and was decorated with 102,000 Novagem Jewels—the tower was flood lighted with search-lights and the shadows were illuminated with rose red light

Digitized by Google

Fig. 86.—Tower of Jewels.

This tower was 438 feet high and was decorated with 102,000 Novagem Jewels—the tower was flood lighted with search-lights and the shadows were illuminated with rose red light

Digitized by Google



Digitized by Google

Digitized by Google

Fig. 56—West Facades of Palaces of Education and Food Products
Illuminated with 35-foot Cartouche standards, each containing three 6.6-ampere luminous arcs

Digitized by Google

Fig. 56.—West Façades of Palaces of Education and Food Products

Illuminated with 36-foot Carborundo standards, each containing three 6-ampere luminous arcs

Digitized by Google

Digitized by Google

Digitized by Google

Fig. 57—Night View Under Trees—West Facade

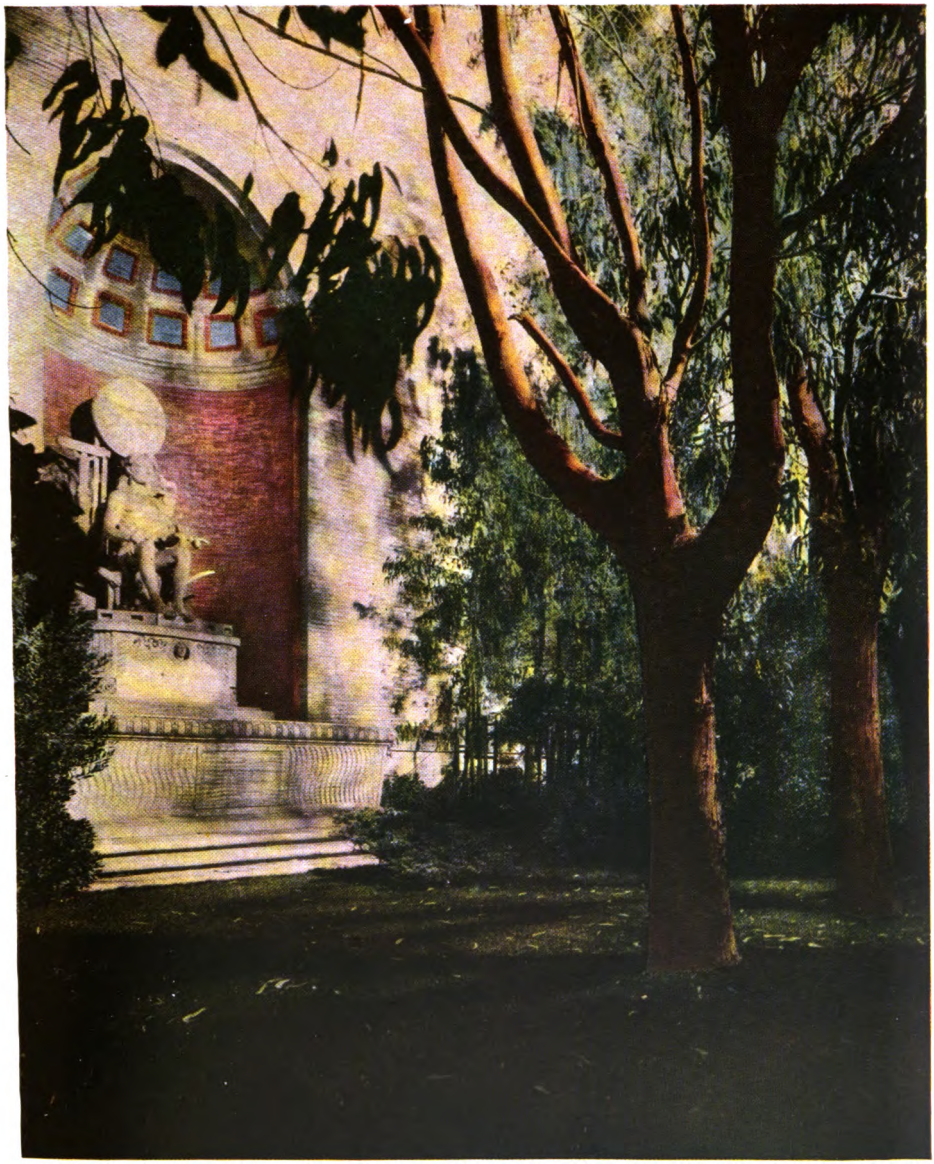
A very striking illustration of light and shadow through the trees, and forming one of the most pleasing effects of the Exposition

Digitized by Google

Fig. 27.—Night View Under Trees. West Façade

A very striking illustration of light and shadow thrown by the trees, and for one of the most pleasing effects of the Exposition

Digitized by Google



Digitized by Google

Digitized by Google

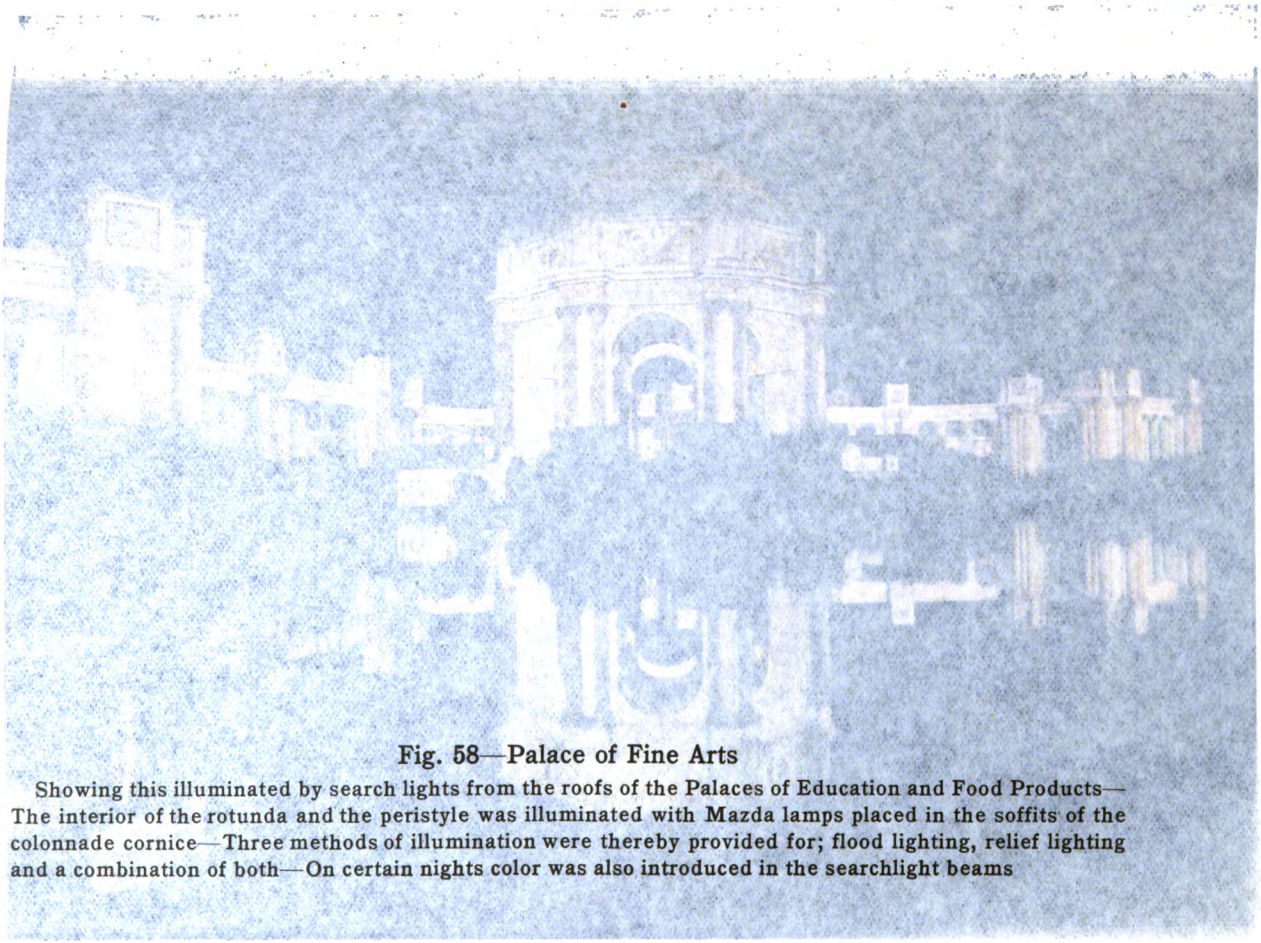


Fig. 58—Palace of Fine Arts

Showing this illuminated by search lights from the roofs of the Palaces of Education and Food Products—The interior of the rotunda and the peristyle was illuminated with Mazda lamps placed in the soffits of the colonnade cornice—Three methods of illumination were thereby provided for; flood lighting, relief lighting and a combination of both—On certain nights color was also introduced in the searchlight beams

Digitized by Google

Fig. 58.—Palace of Fine Arts

Showing this illuminated by searchlights from the roofs of the Palaces of Education and Food Products — structures illuminated with Mazda lamps placed in the soffits of the interior of the rotunda and the peristyle was illuminated with Mazda lamps placed in the soffits of the colonnade courts. Three methods of illumination were thereby provided for; flood lighting, relief lighting and a combination of both. On certain nights color effects were also introduced in the searchlight beams

Digitized by Google

Digitized by Google

Digitized by Google

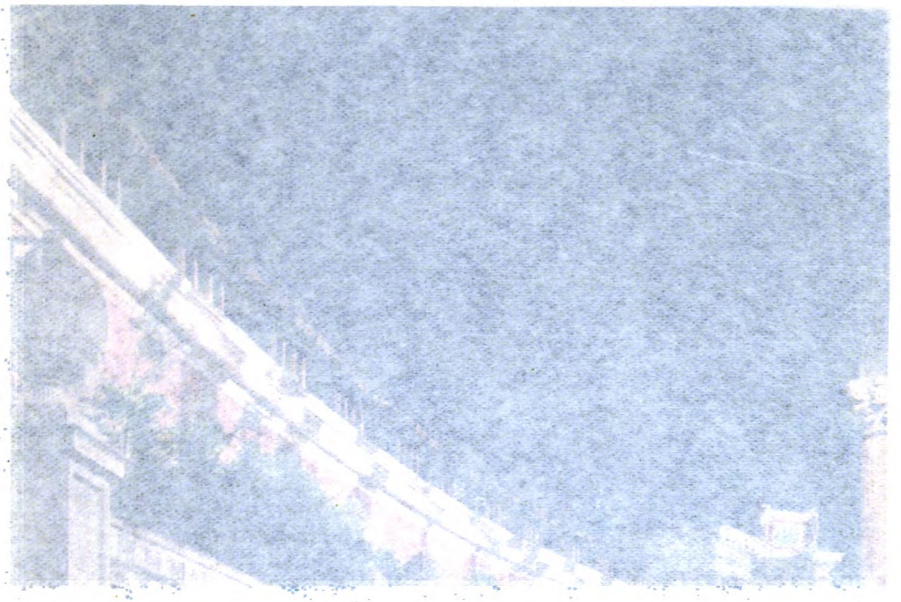


Fig 59—Peristyle Palace of Fine Arts—South Wing
A remarkable night picture

Digitized by Google

Fig 59—Peristyle Palace of Fine Arts - South Wing
A remarkable night picture

Digitized by Google

Digitized by Google

Digitized by Google

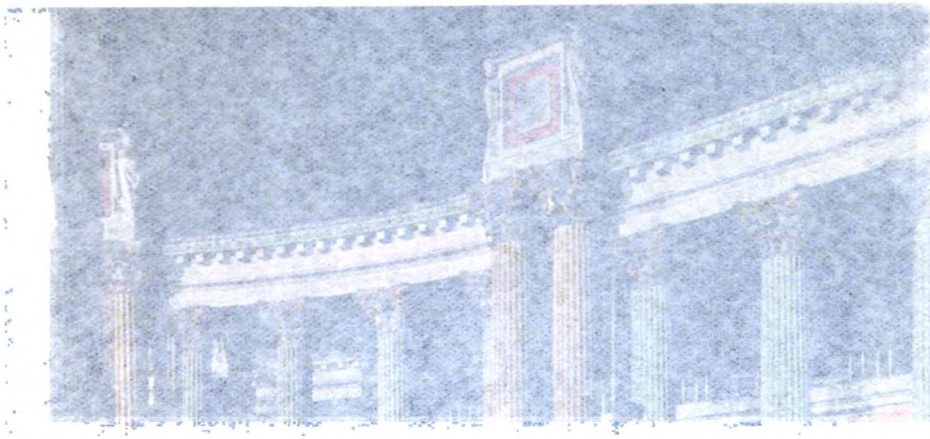
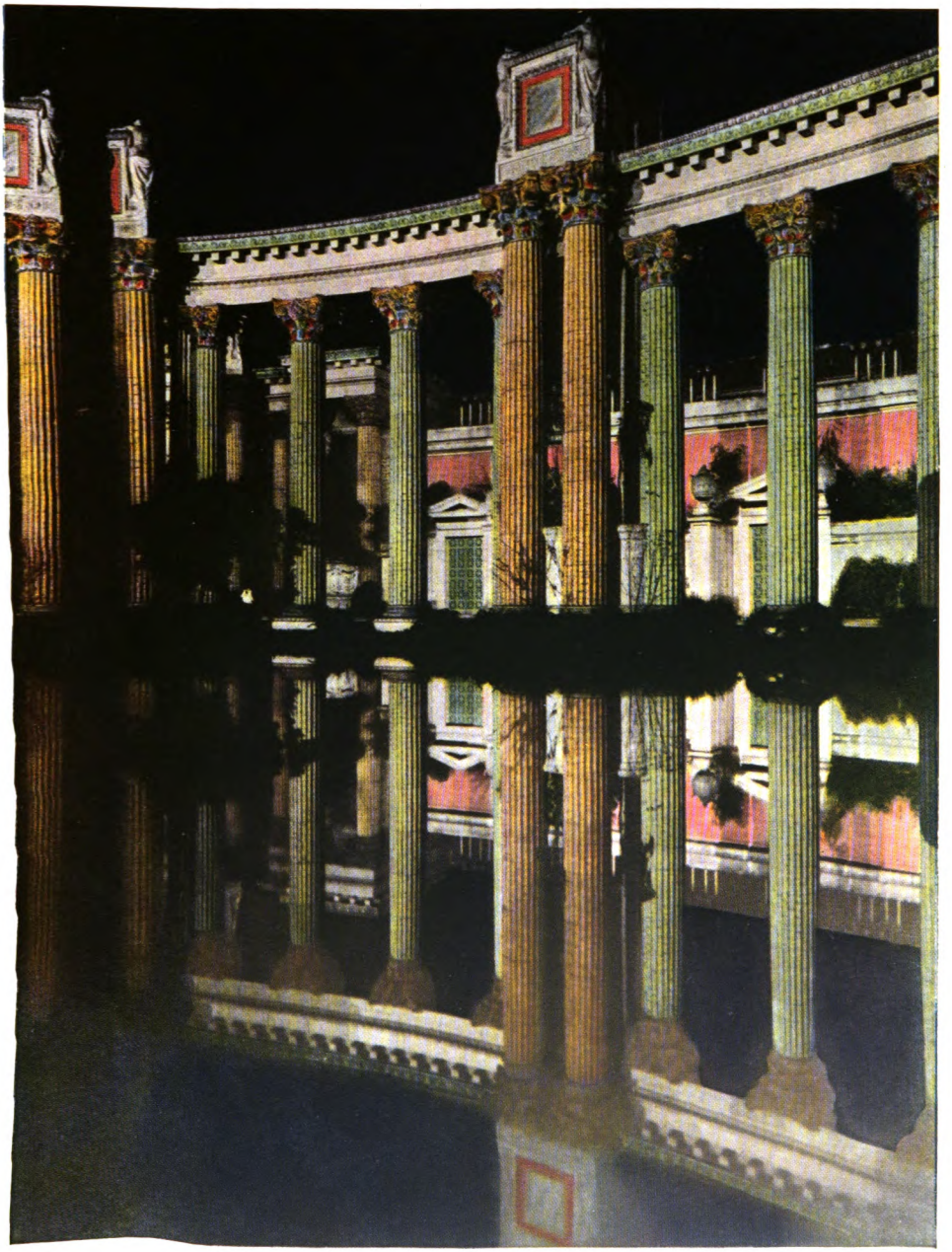


Fig. 60—Reflections of the Colonnade of the Palace of Fine Arts as Seen from the Rotunda

Digitized by Google

Fig. 60—Reflections of the Colonnade of the Palace of Fine Arts as Seen from the Rotunda

Digitized by Google



Digitized by Google

Digitized by Google

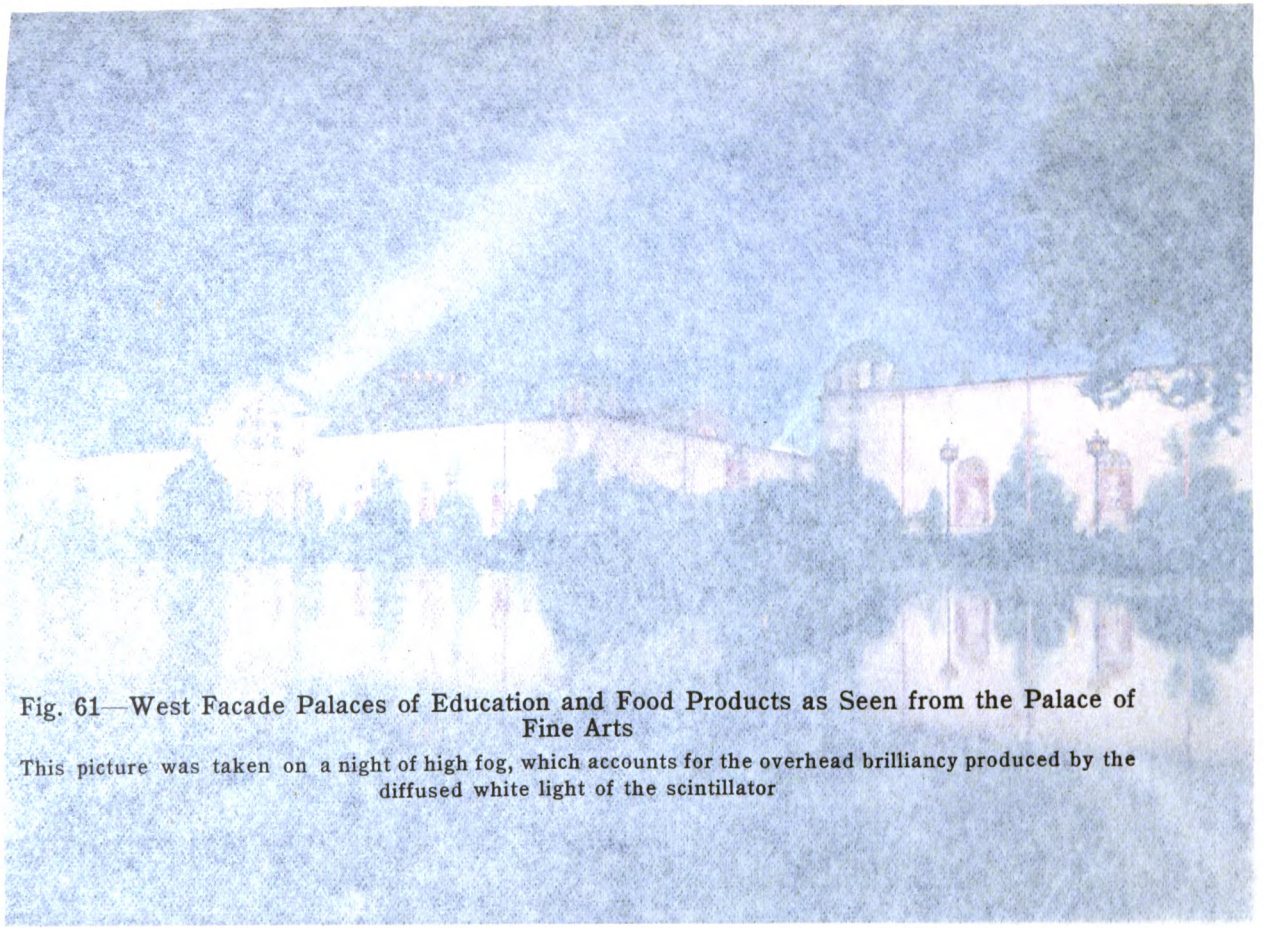


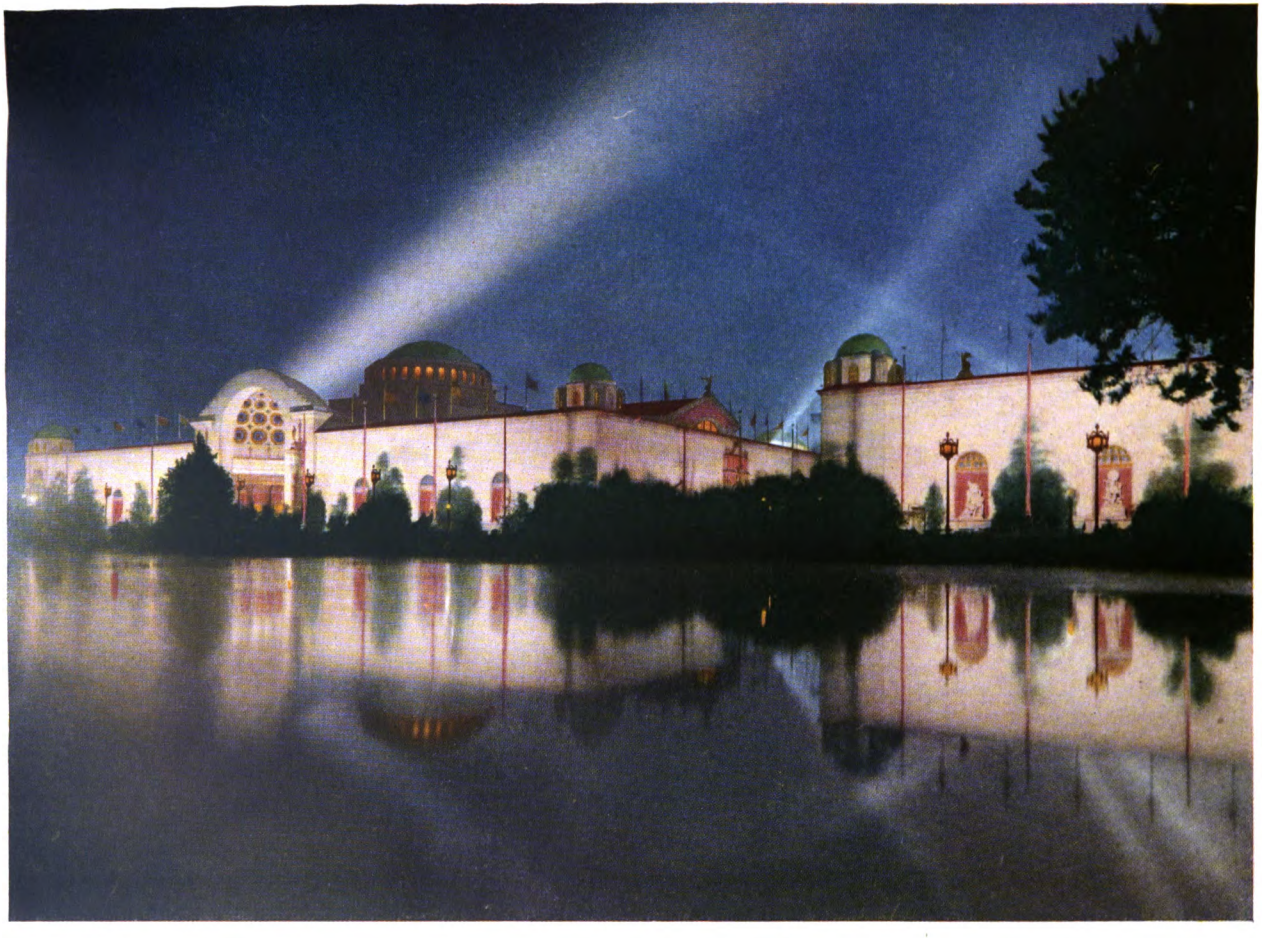
Fig. 61—West Facade Palaces of Education and Food Products as Seen from the Palace of Fine Arts

This picture was taken on a night of high fog, which accounts for the overhead brilliancy produced by the diffused white light of the scintillator

Digitized by Google

Fig. 61 West Façade Palace of Education and Food Products as Seen from the Palace of Fine Arts

This picture was taken on a night of high fog, which accounts for the overhead brilliancy produced by the white light of the scintillator



Digitized by Google

Digitized by Google

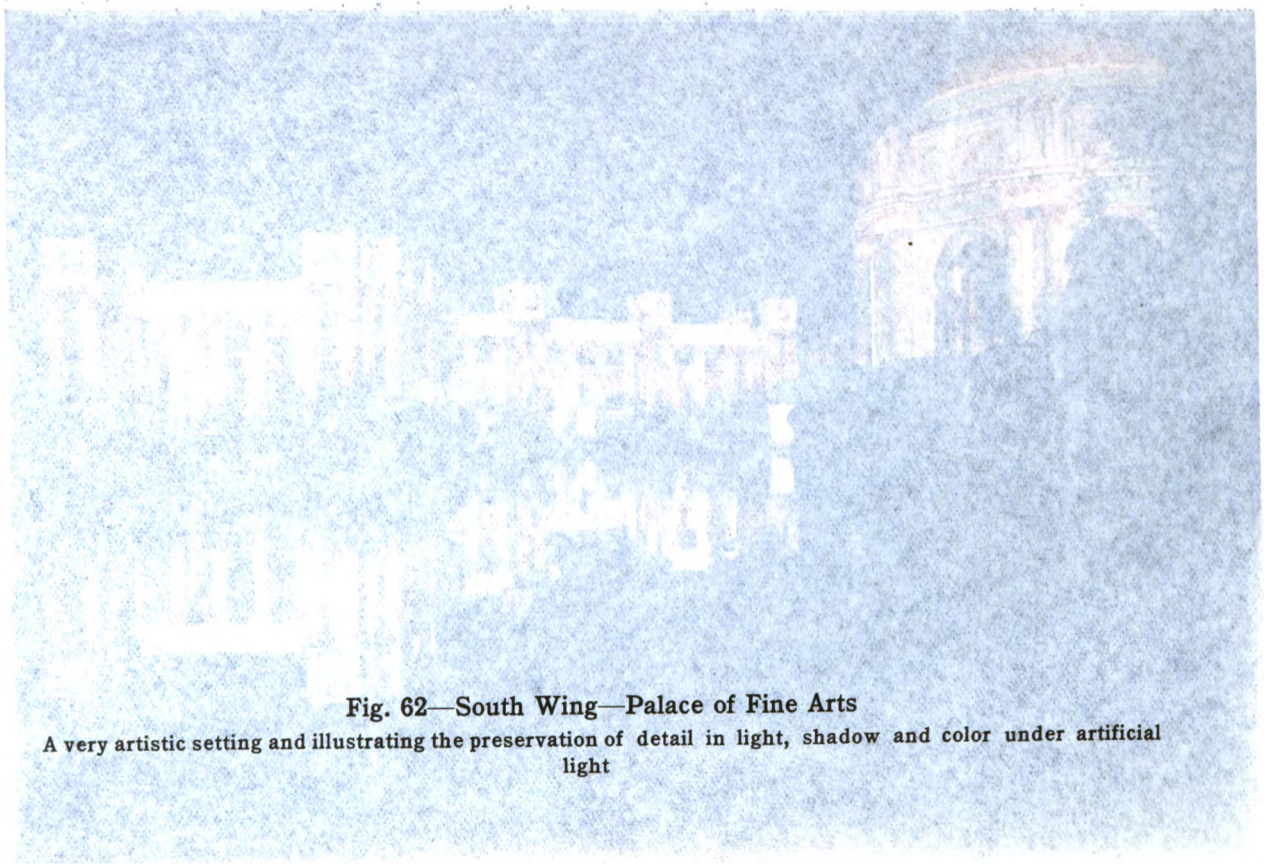


Fig. 62—South Wing—Palace of Fine Arts

A very artistic setting and illustrating the preservation of detail in light, shadow and color under artificial light

Digitized by Google

Fig. 62.—South Wing—Palace of Fine Arts

A very attractive setting was illustrating the preservation of detail in light, shadow and color under artificial light

Digitized by Google

Digitized by Google

Digitized by Google

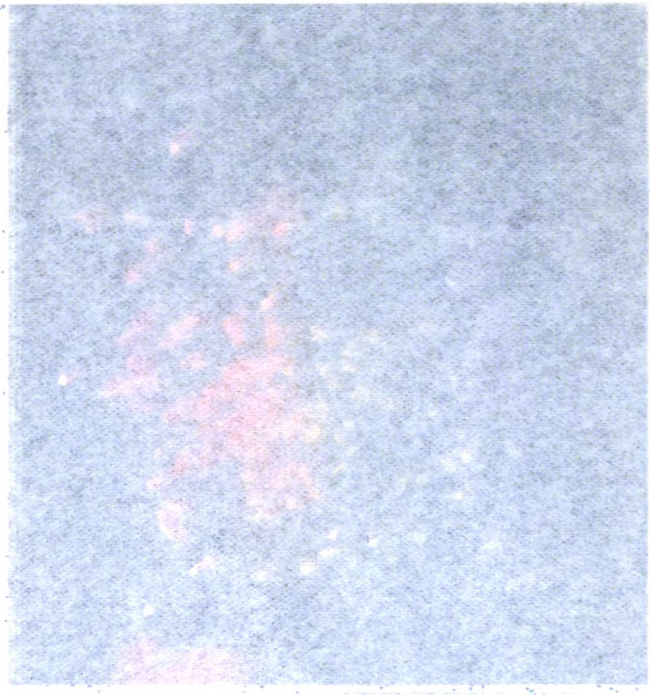


Fig. 63—The Electric-Steam-Color-Scintillator
Taken at the time of the firing of the Zone salvo

Digitized by Google

Fig. 63—The Electric-Steam-Color-Scintillator
Taken at the time of the firing of the Zone salvo

Digitized by Google

Digitized by Google

Digitized by Google

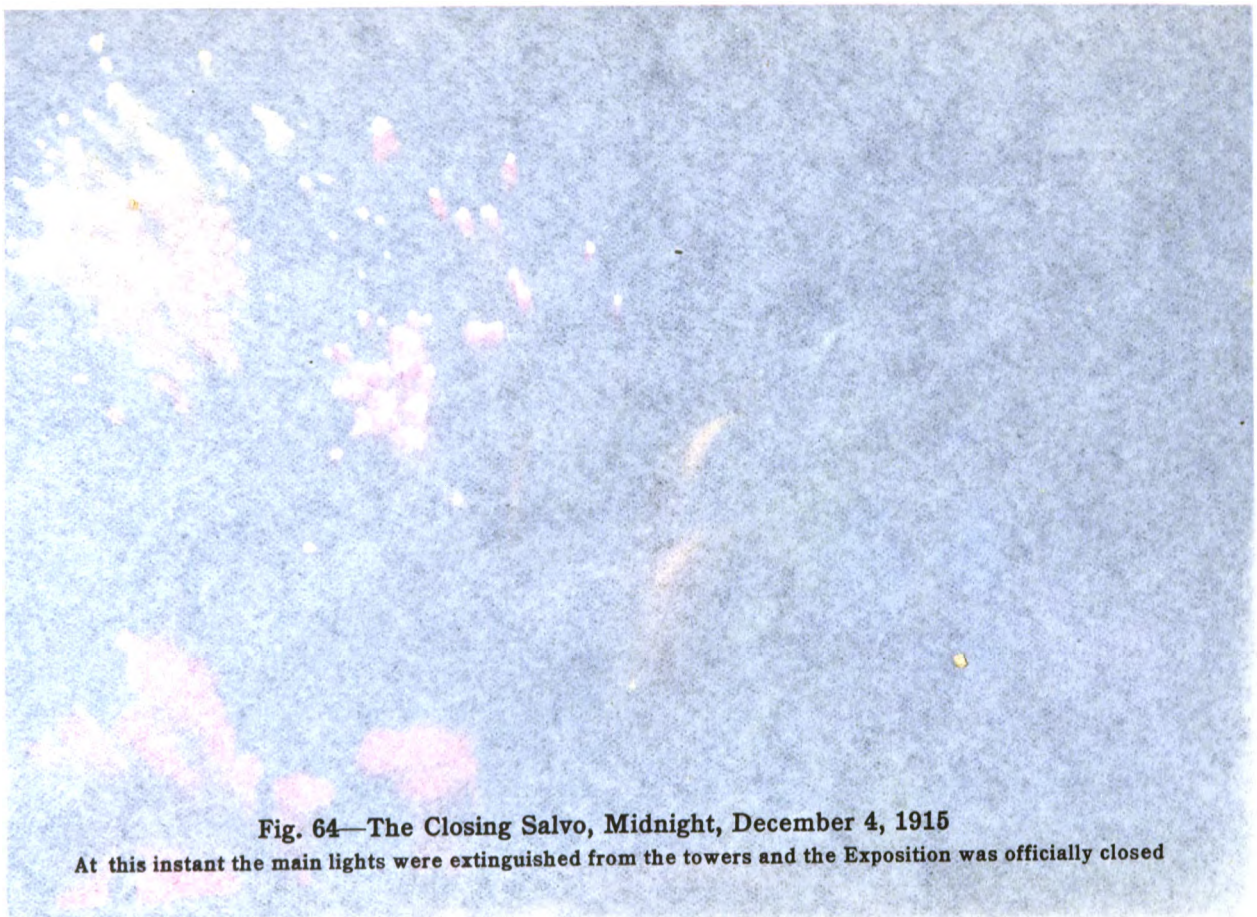


Fig. 64—The Closing Salvo, Midnight, December 4, 1915

At this instant the main lights were extinguished from the towers and the Exposition was officially closed

Digitized by Google

Fig. 64.—The Closing Scene, Midnight, December 4, 1915

At this instant the main lights were extinguished from the towers and the Exposition was officially closed

Digitized by Google

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

THE FUNDAMENTALS OF SUCCESSFUL HIGH-TENSION CABLE JOINTS

BY D. W. ROPER

ABSTRACT OF PAPER

The specifications are intended to apply in general to joints on cables operating at voltages above 10,000, and in particular to joints operating above 20,000 volts. The specifications include the following points:

1. The cable sheath should be cut back from the ends of the conductor a sufficient distance to allow the application of the insulation to the joint without injuring the insulation around the conductors.
2. The copper splicing sleeves should have a carrying capacity at least equal to that of the conductors.
3. The ends of the copper splicing sleeve should be carefully tapered, rounded and finished so as to eliminate all sharp points or edges.
4. The conductors should be separated from each other and from the enclosing lead sleeve by some form of solid insulation that will hold them in a fixed position relative to each other and to the enclosing lead sleeve.
5. The filling compound should have sufficient dielectric strength, which should not be materially reduced at the maximum operating temperature of the cable.
   a. It should be non-hygroscopic.
   b. It should not form cracks in cooling nor during cold weather.
   c. It should be sufficiently fluid when poured that it will flow into all air spaces before becoming chilled.
   e. It should be capable of being readily removed when necessary without injury to the insulation around the conductors.
   f. It should not have an excessive co-efficient of expansion.
6. The insulation should be applied and the compound poured in such a manner that the joint will be without air pockets or voids.
7. All moisture should be carefully excluded from the joint.
8. If filling compounds with low melting point are used precaution should be taken to prevent the compound from running back into the cable at the maximum operating temperature.
9. The initials, or some other symbol, should be stamped on the joint to indicate the name of the Splicer.
10. The joint should be so located, supported and protected that it cannot be readily injured by men working in the manhole.

DURING the past few years there has been a considerable increase in the number of companies installing cables for operation at voltages from 20,000 to 25,000. In some cases the

Manuscript of this paper was received May 3, 1917.

Digitized by Google

companies in making the cable joints have attempted to use methods similar to those which have been found adequate on cables operating at materially lower voltages. The results secured in this manner were frequently disappointing. As the other extreme, some companies have adopted a type of cable joint that required three men a day and a half to complete. In some companies one splicer and a helper make up two joints per day, although three can be made by the same crew under favorable conditions.

It is probable that no two operating companies use the same methods and materials in making up their 20,000-volt cable joints. It is thought that if the engineers engaged on such work would agree upon the fundamental requirements of successful high-tension cable joints, some progress could then be made on standardizing such joints to the advantage of all concerned. The labor cost on the various joints being used by different companies for the same purpose probably ranges from $5 to $30 and the time required ranges from a half day or less to one day and a half. The more expensive joints, which take so long to make, may in some cases be considerably stronger electrically than the cable, and perhaps somewhat stronger than necessary. It is a very serious disadvantage in case of repairs following burnouts to take a day and a half to make up the joints necessary for the purpose. If a temporary joint is made up to reduce this delay, then the joint must be replaced later by the standard type of joint, and in the meantime there is a possibility of joint failure. If the nature of the burn-out has required the use of the cut and try method for locating the trouble it will probably be necessary to stop all other cable splicing work in order to secure enough cable splicers to make up the joints on the cable undergoing repairs.

The following specifications are intended to apply to joints on cables operating at about 20,000 volts, or upwards, but in general they will be found of importance, though in somewhat lesser degree, on cables operating above 10,000 volts.

1. The lead sheath of the cable should be cut back from the exposed conductors so as to provide sufficient space for the application of the insulation around the conductors without danger of cracking the insulation near the end of the lead sheath.

If this point is left to the judgment of the cable splicer he is liable to cut the lead back an insufficient distance so that in order to apply the insulation he will bend the individual con-

Digitized by Google

ductors so sharply near the end of the lead sheath that the insulation will be cracked. In order to prevent this trouble, the distance from the exposed conductors to the lead sheath should be about six or seven inches, depending upon the thickness of the insulation around the conductors. If the joint is to be insulated with wrappings of tape the ends of the insulation around the conductors should be tapered.

2. The copper sleeves or tubes used in splicing the conductors should be of such material and so proportioned that they will have a carrying capacity at least equal to that of the conductors.

As the thickness of insulation in the joint will be greater than in the cable there will be a greater resistance to the radiation of heat from the joint than in the cable. If in addition the copper sleeves have a carrying capacity less than that of the conductor, the temperature of the joint will be further increased. Experience with paper insulated cables shows that the dielectric loss increases with the temperature, and that all forms of insulation have a critical temperature above which the dielectric loss is so great that the temperature will continue to rise due to the dielectric losses until burn-out occurs. This critical temperature is lower for cables impregnated with a resinous compound than with those in which a mineral compound is used. In order to avoid trouble from this cause the splicing sleeve should have ample conductivity. The copper sleeve, as well as the ends of the cable, should be thoroughly tinned, and the soldering of the joint should be carefully done so as to insure that the sleeve is entirely filled with solder. It is essential to have the sleeves heated to the proper temperature before filling with solder. Rolled copper tubing of a proper diameter, and with a length of about four times the diameter of the conductor, makes a very satisfactory sleeve. If the splicing sleeves are made of brass they should be carefully tested to insure proper conductivity.

3. The ends of the copper sleeve should be carefully tapered and rounded, and the outer surface should be finished so as to eliminate all sharp points or edges.

Sharp points on the exterior of the copper sleeve or the conductors will cause an increase in the dielectric stress at these locations, and such points should therefore be very carefully avoided. For this reason the exterior surface of the splicing sleeves should be carefully finished and all small drops or points of solder should be removed with a file or emery cloth so as to leave a smooth, well-rounded surface.

Digitized by Google

4. The conductors should be separated from each other and from the enclosing lead sleeve by some form of solid insulation so that they will retain a fixed position relative to each other and to the enclosing lead sleeve.

The insulation of the joint may consist of

a. Wrappings of insulating tape, or

b. Formed or moulded insulation, such as tubes of paper or other solid insulating material.

If layers of insulating tape are used the splicer should be furnished with gages for determining when the proper amount of insulation has been applied. After this work is completed the three conductors should be bound together in such a manner that they are equally spaced, and at the same time mechanically firm and substantial. This may be done by wrapping bands of tape at several points along each of the conductors, together with some bands around all three conductors at the same locations.

When mechanically formed insulation is used care should be taken to see that the parts are so shaped, placed and fastened that all air will be driven out by the filling compound. Spacers of porcelain, or other suitable material may be found desirable for supporting and holding the conductors at a point between the mechanically formed insulation and the ends of the lead sheath.

5. The filling compound should have the following qualities:

a. It should have sufficient dielectric strength for the purpose, which strength should not be materially reduced at the maximum operating temperature of the cable.

In general there is no great difficulty in securing a compound having sufficient insulating strength at ordinary temperatures. Resinous compounds which decrease rapidly in dielectric strength with increase in temperature do not appear to be as satisfactory as those mineral compounds which have a lower temperature co-efficient. This is particularly important for the compound which is used for applying the wrappings of insulating tape around the conductors.

b. It should be non-hygroscopic.

Moisture is one of the greatest enemies of a good high tension joint and all possible precautions should be taken to exclude it from the compound, or any of the insulating material which enters the joint.

c. It should not form cracks in cooling after the joint is poured, nor during cold weather.

This result is best obtained with those compounds which

Digitized by Google

remain somewhat plastic at the ordinary temperatures and do not become hard or brittle.

d. When heated to the proper temperature for pouring, it should be sufficiently fluid so that it will flow into all air spaces before becoming chilled.

To insure that the filling compound is at a proper temperature for pouring, thermometers should be used, or some simple form of test should be devised which will indicate the proper temperature.

e. The compound at ordinary temperatures should be capable of being readily removed, when necessary, without injury to the original insulation around the conductors.

This is frequently necessary when locating trouble or making alterations, and in such cases it should be possible to open the joint and make the necessary tests, and later re-make the joint without cutting off any of the conductors.

f. It should not have an excessive coefficient of expansion.

After the first filling, time must be allowed to permit the compound to cool before sealing. Ordinarily a small amount of additional compound must be added to fill the void left by the cooling of the compound. One such filling following the original filling should be sufficient.

If the filling compound is liquid or soft at ordinary temperatures, it may be necessary to use a cast metal sleeve in place of the ordinary lead sleeve, or to wrap the insulation with some form of porous tape to act as a cushion between the insulation and the lead sleeve.

6. The application of the insulation and the pouring of the compound should be done in such a manner that on completion the insulation will be solid; that is, without air pockets or voids.

In applying wrappings of tape, the conductors, the splicing sleeve and the insulation around the conductors should first be given a generous coating of some thin insulating compound, applied, preferably, with a brush. The tape should have a lap of about one-half and the compound should be in sufficient quantity and of such consistency that when the wrappings of tape are tightly drawn, all air between the several layers of tape and between the tape and the conductors will be entirely excluded. Additional applications of the compound should be made before applying each layer of tape. Suitable gages should be furnished the splicer so that he can determine when the proper amount of tape has been applied.

Digitized by Google

If some formed or molded insulation is used it should be held in position temporarily by the form of the insulation, or by tying with string or tape. The solid insulation should be so made and held in position in the joint that when slightly tilted at the time of filling, all of the air within the enclosing sleeve will be driven out by the filling compound.

7. All moisture should be carefully excluded from the joint.

For the purpose of excluding moisture it may be necessary to install some temporary shelter so as to prevent drippings from the roof, or contact with the adjacent wall of the manhole. Moisture in the insulating tape should be driven out by dropping it in a vessel containing filling compound heated considerably above the boiling point of water. Rubber gloves should be worn by the Cable Splicer in warm weather, and at other times if the hands are naturally moist. The splicer should also take suitable precautions to insure that no perspiration drops from the face into the joint.

8. If filling compound with a low melting point is used, precautions should be taken to prevent the compound from running back into the cable at the maximum operating temperature.

If the impregnating compound in the cable does not entirely fill the interstices between the strands of the conductors, as well as the insulation, then the filling compound as it becomes fluid may run back into the cable. This would leave voids in the upper part of the cable sleeve and would give a distribution of dielectric stresses that would probably later cause trouble. If such compounds are used the soldering of the splicing sleeve should extend beyond the ends of the sleeve, and in addition, several wrappings of impervious tape should be applied to the conductors where exposed between the splicing sleeve and the original insulation around the conductor.

A thin filling compound may also flow back into the jute filling between conductors if it is not thoroughly impregnated. The use of a filling compound with a low melting point should, therefore, be avoided unless the insulation, the jute, and the conductor are all very thoroughly filled with the impregnating compound.

9. The initials, or some other symbol, should be stamped on the joint to indicate the name of the splicer.

This stamp can be made in the wipe without danger of damaging the joint. Good cable splicers, like other first class workmen, take considerable pride in their work, and it makes them

Digitized by Google

more careful if they know that in case of trouble the maker of the joint can be readily identified.

10. The joint should be so located, supported and protected in the manhole that it cannot be readily injured by men working in the manhole.

For this purpose the cable should be supported at each end of the lead sleeve. If a rope and cement protective coating is applied to the cables in the manholes, the same coating should be extended over the joint. If this is done the joint cannot be injured by being accidentally struck with tools or ends of cable, or by workmen bruising cable with the ladder in entering or leaving the manhole.

Digitized by Google

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

THE INFLUENCE OF DIELECTRIC LOSSES ON THE RATING OF HIGH-TENSION UNDERGROUND CABLES

BY A. F. BANG AND H. C. LOUIS

ABSTRACT OF PAPER

This paper describes a series of tests made to determine the dielectric losses in various kinds of 13,000-volt cable. These losses were found to increase greatly with the temperature and thus become an important factor in the rating of such cables. A method is developed whereby the influence of these losses on the rating can be approximately calculated for duct lines with uniformly loaded cables.

IN THE early part of 1916 a series of tests on 13,200-volt cable under conditions closely approximating operating conditions was conducted in Baltimore, Md. The object was to obtain information relative to the rating of cables at their highest safe capacity, and to analyze the various factors affecting this, such as the influence of dielectric losses.

It was, therefore, attempted:

1. To measure the dielectric losses of cables at different temperatures.
2. To compare cables of various makes and from different manufacturers with each other in this respect, and if essential differences were found to investigate the possible causes of this such as,
3. Different compounds used for impregnating the paper,
4. Percentage of moisture in cable,
5. Thickness of insulation, etc.

Assembly. A nine-hole duct line was constructed in the basement of Sharp Street Station, Baltimore, where the temperature conditions are fairly constant. The layout and dimensions of the duct system are shown in Fig. 1. It consisted of a nine-hole duct, seven ducts being occupied with cable. The duct was 48.5 ft. (14.7 m.) long. The duct was surrounded on sides, top and bottom by sand, which was held in place by a wooden

Manuscript of this paper was received January 10, 1917.

Digitized by Google

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

THE INFLUENCE OF DIELECTRIC LOSSES ON THE RATING OF HIGH-TENSION UNDERGROUND CABLES

BY A. F. BANG AND H. C. LOUIS

ABSTRACT OF PAPER

This paper describes a series of tests made to determine the dielectric losses in various kinds of 13,000-volt cable. These losses were found to increase greatly with the temperature and thus become an important factor in the rating of such cables. A method is developed whereby the influence of these losses on the rating can be approximately calculated for duct lines with uniformly loaded cables.

IN THE early part of 1916 a series of tests on 13,200-volt cable under conditions closely approximating operating conditions was conducted in Baltimore, Md. The object was to obtain information relative to the rating of cables at their highest safe capacity, and to analyze the various factors affecting this, such as the influence of dielectric losses.

It was, therefore, attempted:

1. To measure the dielectric losses of cables at different temperatures.
2. To compare cables of various makes and from different manufacturers with each other in this respect, and if essential differences were found to investigate the possible causes of this such as,
3. Different compounds used for impregnating the paper,
4. Percentage of moisture in cable,
5. Thickness of insulation, etc.

Assembly. A nine-hole duct line was constructed in the basement of Sharp Street Station, Baltimore, where the temperature conditions are fairly constant. The layout and dimensions of the duct system are shown in Fig. 1. It consisted of a nine-hole duct, seven ducts being occupied with cable. The duct was 48.5 ft. (14.7 m.) long. The duct was surrounded on sides, top and bottom by sand, which was held in place by a wooden

Manuscript of this paper was received January 10, 1917.

Digitized by Google

framework. The ends of the cables outside of the ducts were made as short as possible, and were wrapped with sheet asbestos and covered with sand, in order to have these at approximately the same temperature as the part of the cables in the ducts.

Temperature Measurements. As conditions made the use of mercury thermometers impractical in the ducts, we used a differential galvanometer-type thermometer with temperature coils, twenty-seven coils in all being used, each duct containing three coils. As it was important that these temperature coils touch neither the duct nor the cable, they were mounted in a

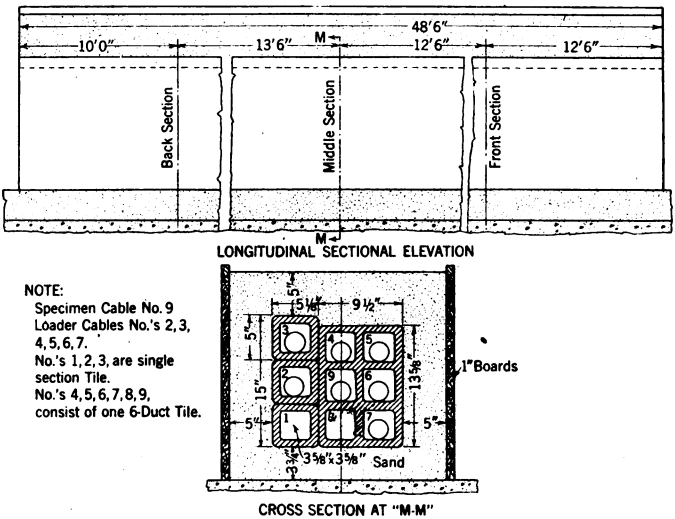


FIG. 1—ARRANGEMENT OF DUCTS AND CABLES IN TEST

little wooden cradle. Temperatures of the copper conductors and lead sheath were determined by rise of resistance method.

Cable Connections and Wiring. Cables in ducts numbered 1, 2, 3, 4, 5 and 6 were all connected in series and carried current only. Cable in duct number 9 carried both current and potential, this being the specimen cable; the different specimens were tried in this duct, the same cable, of course, being used in the other ducts through the test.

Fig. 2 shows the wiring diagram.

Application of Current and Potential. Three-phase current and voltage was applied to the specimen cable. Each phase was short-circuited on itself through current transformers run

Digitized by Google

inverted, and excited from the 5-ampere side; separate current transformers were used to measure the current. High voltage was obtained by using three potential transformers inverted, rated at 200 watts each, 13,200/110 volts; primary and secondary windings were both connected in star. The neutral of the high tension was grounded and connected to the sheathing; consequently, the dielectric strains and losses corresponded with those which occur under practical operating conditions. The dielectric losses were determined by measuring with an ordinary wattmeter the input into the potential transformers on the low-voltage side, and subtracting from this the input with the high-

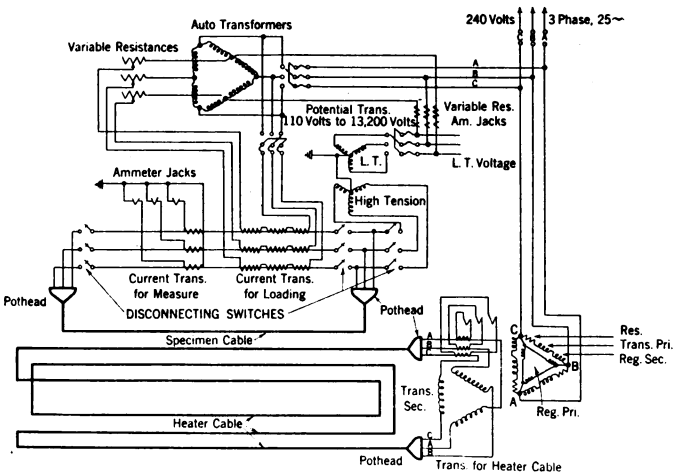


FIG. 2—WIRING DIAGRAM OF TEST

tension cable disconnected, and also the copper losses in the potential transformers, which could be readily calculated. The heater cables carried current only.

Potheads. Standard potheads were used on the cable. In order to correct for the dielectric losses occurring in these, a special test was conducted on a very short piece of cable with two potheads; this test proved these losses to be practically negligible, at least for temperatures not exceeding the actual pothead temperatures occurring during the main test.

Procedure of Tests. Some runs were made with C^2R losses present only, that is, with current only applied.

Dielectric runs were made with current on all cables, and high-tension voltage applied to the specimen cable. Practical condi-

Digitized by Google

tions precluded the application of potential to the heater cables, but the lack of these dielectric losses was compensated for as follows: Starting with current in the heater cables of the same value as in the specimen, dielectric loss of specimen cable was measured when constant temperatures were reached. The current in the heater cables was then increased so that the increased C^2R loss equalled the dielectric loss of the specimen cable. This process was repeated until stable conditions were obtained. On account of the lagging effect of the duct line it was often necessary to continue each test a number of days in order to reach constant conditions.

Results

Specimen Cables. Tests were made in all, on four different specimens of cable from three different manufacturers; all of them were three-conductor, No. 4/0 paper-insulated copper cable; the insulation was distributed as follows:

Specimen A—6/32 in. by 6/32 in. (4.7 mm. by 4.7 mm.)
" B—8/32 in. by 2/32 in. (6.3 mm. by 1.5 mm.)
" C—6/32 in. by 6/32 in.
" D—8/32 in. by 2/32 in.

Dielectric Losses. The curves shown in Fig. 3 show the dielectric losses for these cables expressed in watts lost per foot of cable and plotted against the temperature of the copper conductors. These curves show the marked effect of temperature on the dielectric losses. At low temperatures corresponding to a cold condition of the cables, the losses are low, and about the same for all the specimens, while at higher temperatures the dielectric losses run up rapidly in all cables except specimen D.

These curves show specimen D cable to be much superior in this respect to the others, the dielectric losses being very much lower at high temperatures than the others, and the rate of increase smaller. This rate of increase is important, as it effects the final temperatures, due to the cumulative effect as brought out later on.

Thickness of Insulation. Specimen B—8/32 in. by 2/32 in., (6.3 mm. by 1.5 mm.) shows up better than specimen A. This may be due to the greater thickness of insulation between conductors, since both samples are of the same make and otherwise supposed to be alike. However, it will be noticed that specimen C, which is 6/32 in. by 6/32 in. (4.7 mm. by 4.7 mm.), and of another make shows up slightly better than specimen B, 8/32 in. by 2/32 in. (6.3 mm. by 1.5 mm.).

Digitized by Google

Material of Cables. This markedly superior performance of specimen D shows that there must be some radical differences in material. Samples about 10 in. (25.4 cm.) long were cut from the specimens and sent to a chemist for analysis. The analysis showed that in specimens A, B and C, a rosin oil base is used for impregnating the paper, whereas in specimen D, a mineral oil base is used. Puncture tests made by us on these oils showed but little difference in dielectric strength at high and low temperatures for the mineral oil, whereas in the case of rosin oils the strength decreased greatly with increased temperatures.

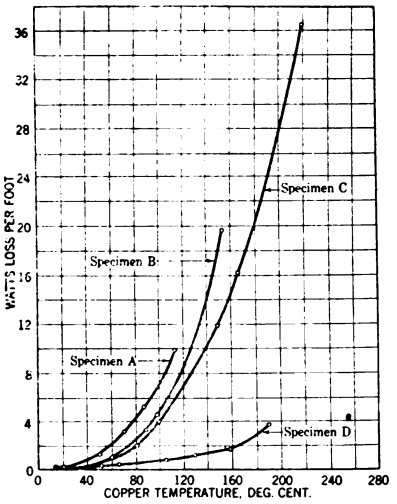


FIG. 3—DIELECTRIC LOSSES IN WATTS PER FOOT LENGTH OF CABLE AS DEPENDING ON THE TEMPERATURE OF THE CONDUCTORS

The difference in impregnating compound we believe is, therefore, the greatest cause producing the marked difference in performance.

Analysis for moisture was made also on 5 in. (12.7 cm.) pieces of the specimen cables. Specimens A, B and C using rosin oil compound showed the same relative order of moisture as dielectric losses. Specimen D showed a high percentage of moisture, and yet has the lowest dielectric losses; this fact can only be taken as a proof that the nature of the compound, which here is a mineral oil, has a greater influence than the per cent moisture.

Relative Temperatures. The test on the Sharp Street duct line shows comparatively small differences between copper, lead and duct temperatures, under constant conditions. In the run made on specimen D cable with 175 amperes on the heater and specimen, and 13,200 volts on the specimen, the total watts lost per foot on the specimen was, for instance, 6.5 watts and the temperature as follows:

Copper Temperature	89 deg. cent.
Lead	86 deg. cent.
Duct	82 deg. cent.
Room	20 deg. cent.

Digitized by Google

The reason for the close proximity of these temperatures to each other in spite of the high rise above the room temperature is essentially the fact, that the main temperature rise in our case

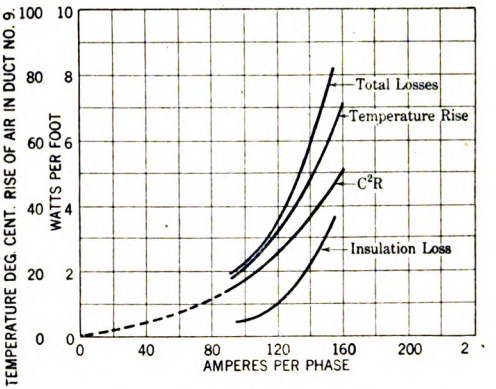


FIG. 4—CURVES SHOWING RELATION OF C^2R AND DIELECTRIC LOSSES IN SPECIMEN *A* IN SHARP STREET TEST

took place in the dry sand surrounding the duct line and that this rise was secured by moderate loads on the cables. This condition imitates very well actual duct conditions where ducts pass under streets through dry soil or ashes.

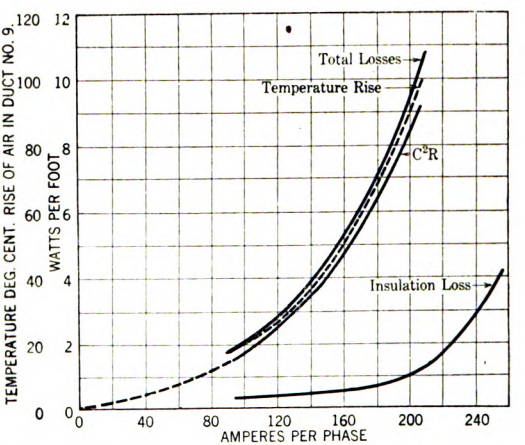


FIG. 5—CURVES SHOWING RELATION OF C^2R AND DIELECTRIC LOSSES IN SPECIMEN *D* IN SHARP STREET TEST

Relative Losses. A comparison of C^2R and dielectric losses can only be made for specific cases, as the C^2R losses depend mainly on current carried, and slightly on temperature, and the

Digitized by Google

dielectric losses for a given cable and voltage only on temperature. Curves shown on Figs. 4 and 5 show this relation for specimens A and D, which constitute the two extreme cases of the test. The conditions were such that 100 amperes produced no excessive temperatures, so that all the specimens had a dielectric loss of less than 25 per cent of the C^2R at 100 amperes. It will be noticed that for specimen A (See Fig. 4) the dielectric loss runs up very rapidly at currents above 100 amperes, a condition which would be far more aggravated if the initial room temperature were higher than the one at which the test was made (18 deg. cent.). With higher currents the ratio of dielectric to C^2R loss increases rapidly and approaches 100 per cent. Only specimen D (Fig. 5) shows no great increase of dielectric loss as the load and

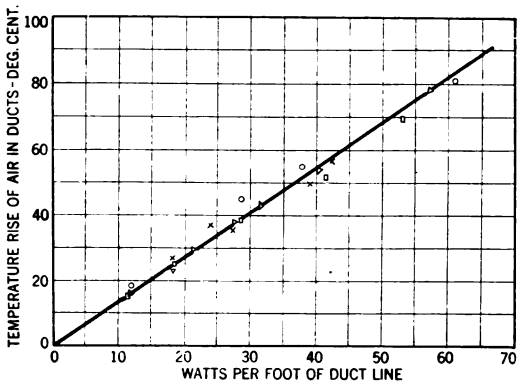


FIG. 6—DISSIPATING CURVE OF SHARP STREET EXPERIMENTAL DUCT LINE

temperature go up, and the ratio of dielectric to C^2R even decreases with increased current and temperature, this holding good for a range of current well within practical working limits; even an increased room (or soil) temperature would not affect this to any great extent.

Heat Dissipating Curve. From the amperes per phase, the resistance, and the dielectric loss measured we can calculate the total energy lost in the duct line and from this plot a curve between watts lost per foot of the duct and the temperature. This is done in Fig. 6. Since this curve represents constant conditions, the watts loss are a measure of the heat dissipated by the duct system at various temperatures. The curve shows that this relation is practically a straight line. In Fig. 6, this tempera-

Digitized by Google

ture plotted refers to the air in the duct. Other experiments made by the writers proved, that also when we plotted the temperature rise of the copper conductor above soil or any one of the cables against the watts lost per cable, per foot, the result would be a curve very close to a straight line. In the following calculations this relation is therefore always taken to be a straight line. It is also assumed that the relation is independent of whether the heat dissipated is generated in the copper by the current or in the insulation by the voltage.

Any duct line will of course have its own particular dissipating curve.

Critical Point (Temperature and Current). The effect of dielectric losses on the heating of cables is cumulative, *i.e.*, when a cable has reached constant conditions with low-tension currents only applied and high voltage is then added, certain definite dielectric losses will occur and produce a temperature increase; but, on account of the higher temperature thus reached an increase of the original dielectric losses will take place, which fact again increases the temperature and so on indefinitely; there is, therefore, always a possibility that a critical point may be reached where the heat generated in this way is larger than the heat that can be carried away; if this point has been reached and passed the temperature of the cable will evidently rise indefinitely until break down occurs and will do so even for a constant current load. That such a critical point exists for any high-tension cable surrounded by a poor heat conductor has been repeatedly pointed out. (See especially the N. E. L. A. Cable Report—1913). In our tests we were able to produce this condition on specimen cables A, B and C, by means of the "compensated" runs mentioned above. In these runs it was found that a point was reached in the loading where it was not any longer possible to compensate, as the dielectric losses ran up faster than the heat dissipating power of the duct line. In the dielectric curves, Fig. 3, the lower points are plotted from values measured in the compensated runs; when compensation was no longer possible a constant current was maintained on the heater cable *and the dielectric losses on the specimen cable would then gradually raise the temperature of this cable until destruction.* The higher points in Fig. 3 are plotted from this last part of each test. Only on specimen D did we not determine the critical point. While it doubtless exists, it would evidently in this case be found at a higher temperature than reached in our test. (190 deg. cent.)

Digitized by Google

As it is evident that very unstable and dangerous conditions exist in a high-tension duct line, where this critical point has been reached and as it will be found in many practical cases, that this point, therefore, rather than any special high temperature, constitutes the danger line for the rating of high-tension cables, we have, in the following, developed a method for the determination of this critical point for any duct line, with uniformly loaded cables, and on the whole calculate the temperatures that will be reached for given loads under due regard to the dielectric losses. To do this it is necessary to know only the following few data, which can be found experimentally.

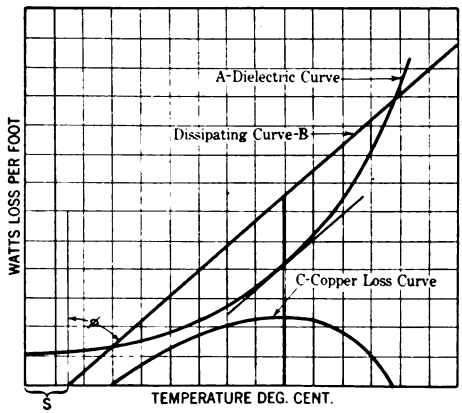


FIG. 7—GRAPHIC DETERMINATION OF THE PERMISSIBLE CURRENT AND THE CRITICAL TEMPERATURE FOR A DUCT LINE, WHEN ITS DISSIPATING CURVE *B*, ITS DIELECTRIC CURVE *A*, AND THE SOIL TEMPERATURE *S* ARE KNOWN

Calculation of the Influence of Dielectric Losses. 1. The dielectric characteristics of the cable, expressed in a *dielectric curve* as for instance those shown on Fig. 3.

2. The heat characteristics of the duct line and the cable expressed by the heat *dissipating curve* for same.

3. *The soil temperature* at a distance sufficiently far away from the duct line to be unaffected by the heat produced in the duct.

Let curve *A* in Fig. 7 represent the dielectric loss curve for the cable installed.

Let curve *B* represent the dissipating curve for the duct line at a given soil temperature *S*,

Digitized by Google

If we now assume that we have reached constant conditions where no heat is used for increasing the temperature of cable and duct, the watts dissipated as indicated by curve B are equal to the total losses generated which consist of dielectric and C^2R losses.

If we therefore deduct the dielectric losses (as shown in curve A) from the total losses (curve B) we get the C^2R loss. This subtraction is done graphically in Fig. 7. The result is curve C which represents the copper losses. From this curve we can calculate the corresponding current for any number of points from the formula

$$C = \sqrt{\frac{W}{3R}}$$

Where W = Watts taken from curve C.

R = the resistance of one conductor (at a temperature taken from the corresponding point of curve B).

In Fig. 7 it is assumed that the soil temperature is a constant S. A change in soil temperature which is the base for the duct and cable temperatures means a parallel shifting of the dissipating curve and therefore produces an entirely new copper loss curve C.

Determination of the Critical Temperature by Tangent Method. It will be seen from Fig. 7 that curve C, which represents the copper losses, has a maximum point. This means that for temperatures beyond this point, less current can be carried than at lower temperatures and if the current is not reduced the temperatures will evidently continue to rise indefinitely. This point corresponds therefore to the *critical point* as defined above.

A glance on the same drawing, Fig. 7, will also show geometrically that this maximum ordinate in curve C (copper loss curve) is determined by drawing a tangent to the dielectric curve parallel with the dissipating curve. In other words if we only know these two curves for a given duct line, we can determine the critical point by drawing such a tangent; the abscissa to the point of tangency will then indicate the critical temperature for this particular case. Physically one can express the same fact by saying that at this point the rate of increase in the dissipating power of the duct line equals the corresponding rate of increase in the dielectric losses generated (curve A), while beyond this point the latter rate will be the larger; hence the unstable condition.

Digitized by Google

The fact that we can determine the critical point in this way is important since it allows us to grasp, at a glance, the essential facts about the critical temperature for a given case.

Conditions Which Influence the Critical Temperature. It shows for instance—1. That for a given duct line with a definite number and make of cables, the critical point will always be reached at the same actual temperature (critical temperature) independent of the original soil temperature.

2. That this critical temperature will be the lower, the steeper the dielectric curve is, and the greater the angle ϕ of the dissipating curve; cables with a low and flat dielectric curve are, therefore, greatly preferable.

3. The angle ϕ of the dissipating curve depends on the character of the soil surrounding the duct line. If the surroundings consist of poor heat conductors, like dry sand or ashes, it will result in a greater temperature rise for the same watts lost; this means a greater angle ϕ of the dissipating curve and therefore a lower critical temperature.

4. In a similar way will the critical temperature be influenced by the number of cables installed in a duct line. With the same energy lost per cable we get a total loss in a duct line directly proportional with the number of cables installed and since the heat dissipating surface of the duct line only increases at a slower rate, the result is a higher temperature rise of the duct for the line with the many cables. Hence the greater angle ϕ of the dissipating curve and the lower critical temperature.

These facts are important since they show that dry soil surrounding a duct line and the installation of too many cables in one line should be avoided, as far as possible. Not only do both conditions tend to produce much higher temperatures for the same energy lost, but since the critical temperature is lower, it means also that cables in such a line can only stand a lower temperature.

Example of Application. In the theory developed above, it is clearly pointed out, that each duct line represents its own individual problem in rating. The examples given below are therefore to be taken only as illustrations of the application of the principles involved and not as giving definite ratings—always applicable.

Fig. 8 shows a section of a duct line in Baltimore, Md. It consists, as shown, of twenty ducts of vitrified clay, arranged in two sections. It contains at present fourteen current carrying

Digitized by Google

cables of which thirteen are operated at 13,000 volts and one at 4000 volts. All of them are number 0000 copper cable, three-phase, lead-covered, and with an insulation 6/32 in. by 6/32 in. (4.7 mm. by 4.7 mm.).

For this duct line the dissipating curve was calculated from the known load, the dielectric characteristics of the cable and a large amount of measurements of the copper, duct and soil temperature at the very hottest sections of the line.

In Fig. 9 this dissipating curve is shown as B_3. It should be understood that in this case it is calculated so as to represent temperature rise of the copper of the hottest cable above the soil surrounding the duct line.

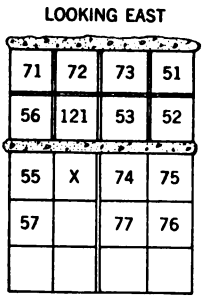


FIG. 8—SECTION THROUGH FAYETTE STREET DUCT LINE

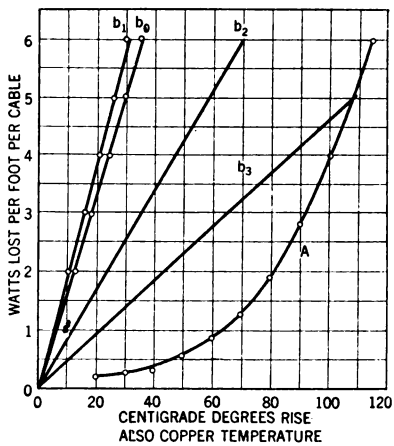


FIG. 9—DISSIPATING CURVES FOR VARIOUS DUCT LINES

By means of this dissipating curve and the dielectric curve we can now calculate the final copper temperatures for various loads and soil temperatures by means of the procedure described above.

A number of such calculations has been made and the results shown in Fig. 10 for initial soil temperatures of 0, 10, 20, 30 and 40 deg. cent.

It will be seen that at about 65 deg. cent. the curve starts bending backwards; this is therefore the critical point for this particular duct line.

In order to play safe it is evident that the average temperature on a steady load run should never be allowed to reach this critical

Digitized by Google

point. Let us assume that 10 deg. cent. below this point, *i. e.*, a final copper temperature of 55 deg. cent., is the highest temperature we will permit. It is then evident that the curves in Fig. 10 give us a cable rating as depending on the soil temperature. This rating is shown in Fig. 11 (curve marked specimen C). As abscissas are used the initial soil temperatures in 0 deg. cent., while as ordinates are used both amperes, *i. e.*, continuous carrying capacity and also the kw-hr. output per day, corresponding to such a continuous load at power factor of 1. From this curve it may be noted, for instance, that at freezing temperature of the soil, the cables can carry safely 106 amperes con-

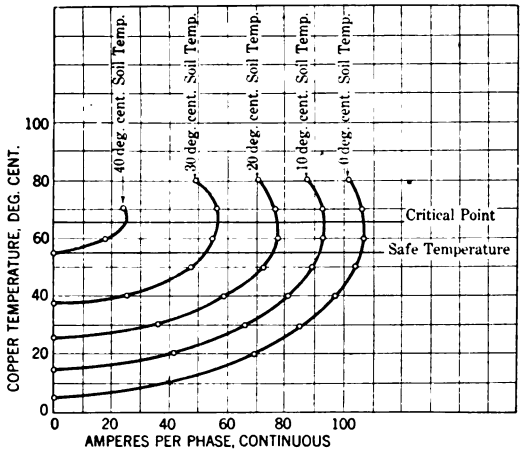


FIG. 10—TEMPERATURES OF CONDUCTORS REACHED IN A HIGH-TENSION DUCT LINE WITH 13 CABLES INSTALLED AS DEPENDING ON THE LOAD AND SOIL TEMPERATURE—SPECIMEN *C* DIELECTRIC CHARACTERISTICS ARE ASSUMED

tinuously, or 58,500 kw-hr. per day, while at a soil temperature of 40 deg. cent. or above, no load whatever can be carried.

Cable Rating with Cables of Different Make. The cable rating thus determined for the above described duct refers to cables of dielectric characteristics as specimen C in Fig. 3. The rating of the same duct line with cables of dielectric characteristics as specimens A, B and D has also been figured out and is shown in Fig. 11. For the specimens A and B the safe copper temperature has been assumed to be 10 deg. below the critical temperatures (60 deg. and 50 deg. respectively) in the same way as was done for specimen C above. For specimen D where the dielectric

Digitized by Google

losses increase so very much slower with increasing temperature than they do on the other specimens, it was found, however, that the critical point would not be reached before the copper temperature was 160 deg. cent. Hence the rating of this cable would not be limited at all by the critical temperature of the duct line, but would rather depend on whatever temperature could be considered safe for the insulation itself. If we follow the A. I. E. E. Rules laid down in section 677 and adopt 72 deg. cent. as a safe temperature for this cable, we get the rating shown by curve *A*, Fig. 11. As it is probable that the temperature limits set by the Institute Rules in its section 677, are made so

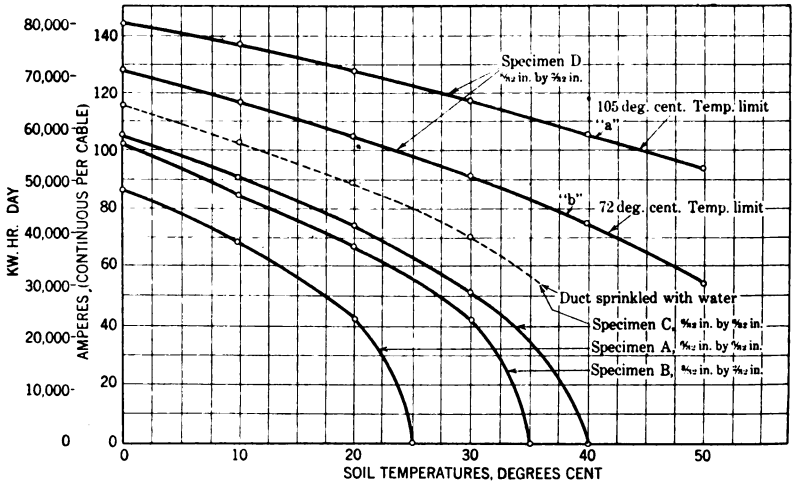


FIG. 11—CURVES SHOWING HOW THE SOIL TEMPERATURE AFFECTS CABLE RATING IN FAYETTE STREET DUCT LINE FOR CABLES OF VARIOUS DIELECTRIC CHARACTERISTICS

low on account of a vague fear of reaching a critical temperature for the cables and as it has been shown that for specimen D cable, no such fear need be entertained, it would, perhaps, seem more reasonable to use as a permissible temperature for this cable the figure (105 deg. cent.) given in the A. I. E. E. Rules, section 377 for Class A insulation. Corresponding to this we get curve *B*, Fig. 11.

A comparison of all these curves shown on Fig. 11 gives a very clear impression of the extreme limitation the dielectric losses may put on cable ratings, especially in hot summer weather. As an illustration let us consider a summer condition with a soil

Digitized by Google

temperature of 21 deg. cent. (At the average depth of the duct line.)

To this corresponds the following ratings:

Specimen	A	38	amperes	21,000	kw-hr.	per	day	
"	B	65	"	36,000	"	"	"	"
"	C	72	"	40,000	"	"	"	"
"	D	127	"	71,000	"	"	"	"

Or a rating more than three times greater for specimen D than for A.

In winter time, of course, more load can be carried on all types of cables, but the *difference* in rating is less striking.

A number of other practical cases with the number of cables in a duct line varying from 2 to 12 were also calculated. With dielectric curves of the characteristics found for specimens A, B and C the critical temperature varied from 50 deg. to 90 deg.

In view of these facts it seems reasonable to propose,

1. That high-tension cables always should be purchased under certain guarantees as to dielectric losses at various temperatures.

2. That for determining the load carrying capacity of a given high-tension duct line the critical temperature should be investigated and the rating made so that the highest copper temperature (under steady load conditions) always would remain a definite number of degrees centigrade (say 10 deg. cent.) below this point. If the critical temperature on the other hand is found to lie so high that temperatures lower than this may be destructive to the installation these naturally would govern; but in such a case the same temperature should be considered permissible for high-tension cable as for a low-tension cable.

In this paper only constant load conditions have been considered.

The above investigation has been conducted under the auspices of the Consolidated Gas, Electric Light and Power Co., of Baltimore and the Pennsylvania Water and Power Co.

Digitized by Google

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

INSULATION CHARACTERISTICS OF HIGH-VOLTAGE CABLES

BY W. S. CLARK AND G. B. SHANKLIN

ABSTRACT OF PAPER

The insulation characteristics of different types of single- and three-conductor cable, determined largely by dielectric energy loss measurements, are discussed in detail. Particular attention is given to paper insulated cable, both new cable and cable that has been in service being considered. Varnished cambric and different grades of rubber insulation, as well as cable compounds are also dealt with briefly.

THE experience of operating companies here in America over a period of years shows that practically all failures on high-voltage underground cable systems can be attributed to heating. The cable line on which failure occurs is usually not heated over its whole length to a dangerous temperature, but only at certain points, generally known as "hot spots."

The "hot spot" temperature plays an important part in all sections of an electrical system, but in no part of a system is it so much the limiting feature as in the underground cables, and in consequence, in no other part of the system does dielectric energy loss at normal frequency and voltage play such a predominating part. This is so because of the rapid rise of dielectric loss with temperature and its cumulative tendency at high temperature.

DISCUSSION OF DIELECTRIC ENERGY LOSS MEASUREMENTS

The purpose of this paper is to show the value of dielectric energy loss measurements in studying cable designs and as an assistance to the manufacturers and users of cable. To obtain the greatest usefulness, the study of energy loss should, of course, be paralleled with other tests and observations, and this we have attempted to do.

These data were taken with the object of representing operating conditions as closely as possible. A constant frequency of

Manuscript of this paper was received May 16, 1917.

Digitized by Google

60 cycles was used throughout. There are so many variables to be considered that it requires numerous data to include them all, and this complicates things quite enough without bringing in frequency variations. In every case the voltage range used gives readings well above and below the operating voltage of the sample.

In duct operation, the copper temperature is only a few degrees higher than that of the lead sheath and the temperature is graded through the thickness of insulation. It is not desirable to represent this condition in the laboratory, even if it were possible to do so with any degree of accuracy. The temperature gradient would not be the same in samples of different cross sections and the measurements on these would not be comparable. A very complicated variable is eliminated by heating the cross section to a uniform temperature. This represents conduit conditions fairly closely. The greatest loss per cm^3 occurs in the insulation next to the conductor, where the stress is greatest, and the increase brought in by having the outer wrappings at a slightly higher temperature than they would be in the ducts, is not important. At any rate the losses measured are on the safe side, that is, higher than would occur in operation.

Method of Test

The readings were taken by the "compensated dynamometer wattmeter method," fully described in an article published last year. * The principle of this method is simply a correction of all phase angle errors by reference to a standard high voltage variable air condenser having a negligible phase difference from 90 deg. The possible errors that can be introduced and checks upon the accuracy of the method are discussed in detail in the article.

A smooth-core generator and special testing transformer were used and gave a sine wave under all conditions of test as shown by oscillographic records. This is not of great importance, however, as distortion of wave shape within reasonable limits does not affect energy loss measurements. Monasch † brought this out in an interesting way.

* "Compensated Dynamometer Wattmeter Method of Measuring Dielectric Energy Loss," by G. B. Shanklin, *General Electric Review*, Oct. 1916.

† See "The Loss of Energy in the Dielectric of Condensers and Cables" by Dr. Bruno Monasch. London *Electrician*, Vol. 59, p. 416.

Digitized by Google

Paper-Insulated Cable

It is an interesting fact that paper-insulated cable, the most generally used of all types of cable, is susceptible to the widest variation in its insulation characteristics. The reason is not hard to find but it is hard to put on paper in condensed form.

In practically all of the standard types of impregnated or treated fibrous insulations, with the exception of paper cable insulation, treatment is given after it is thoroughly filled to render the filler solid and firmly "set." This is called "curing" and it is well known that a cured insulation is more stable and uniform than an "uncured" one, although it does not necessarily have inherently better electrical characteristics. Now, in paper insulated cable the filler remains in a semi-liquid or viscous form and the material operates throughout its life in an "uncured" or "green" condition. It is not an inert mass but is chemically, electrically and physically "alive." It will not be active in any of the above senses if the ingredients and processes are properly chosen, still it is "alive" and every detail of its manufacture must be carefully watched.

The paper and jute serve as mechanical spacers and the characteristics of the insulation as a whole are determined to a great extent by the quality of the filling compound. In making this statement it is assumed that the paper, jute and compound are initially free of moisture and other conducting impurities. In choosing the compound we must not only be sure of its having the best insulating properties when first put in the cable but we must also be sure that it is chemically stable and that it will not react chemically with either the paper, jute or copper under the temperature and voltage stress met with during its years of operation.

Tests on Compound

The 60-cycle dielectric energy loss data on a standard type of mineral hydro-carbon base cable compound are given in Table I.

Space will not allow the presentation of curves showing all the different characteristics. They are all interesting and well worth studying from the table but only those curves will be given that bring out particular points of interest. This plan will have to be followed throughout the paper. The tables are submitted with the readings arranged consecutively in the same order in which they were taken.

Fig. 1 shows the variation of power factor and permittivity with temperature. The relative permittivity decreases with

Digitized by Google

temperature and there is a very decided hump in the curve between 50 and 75 deg. cent. It is over this range that the compound is gradually changing from a solid to a semi-liquid state, with a corresponding expansion of volume and decrease in specific gravity.

The permittivity curve is replotted in Fig. 2 for comparison with a corresponding curve of a typical heavy, mineral insulating

TABLE I.

MINERAL HYDROCARBON BASE CABLE COMPOUND NO. 1

Frequency 60 cycles

Temp. deg. cent.	kv./cm.	W/cm.^{3} 10^{-3}	I/cm.^{2} 10^{-6}	P.F. per cent.	K	ρ 10^{10}
105	6.06	0.776	0.486	26.3	2.322	4.71
	8.05	1.410	0.641	27.3	2.295	4.58
	10.08	2.260	0.800	28.0	2.283	4.52
	12.08	3.280	0.960	28.2	2.280	4.44
	14.94	5.040	1.182	28.3	2.284	4.44
	18.10	7.520	1.442	28.6	2.292	4.40
75	6.06	0.202	0.492	6.75	2.421	18.10
	8.05	0.356	0.651	6.74	2.415	18.20
	10.08	0.557	0.812	6.86	2.412	18.30
	12.08	0.817	0.972	6.95	2.406	17.80
	14.94	1.282	1.194	7.08	2.400	17.40
	18.10	1.910	1.445	7.27	2.394	17.60
48	6.06	0.0410	0.493	1.44	2.436	90.3
	8.05	0.0702	0.652	1.34	2.427	92.4
	10.08	0.1045	0.815	1.27	2.421	97.6
	12.08	0.1532	0.982	1.30	2.412	94.8
	14.94	0.2370	1.195	1.32	2.406	94.2
	18.10	0.3570	1.450	1.35	2.406	94.2
32	6.06	0.01260	0.494	0.422	2.442	295
	8.05	0.01982	0.653	0.377	2.433	320
	10.08	0.02916	0.814	0.351	2.430	335
	12.08	0.04260	0.979	0.359	2.433	341
	14.94	0.06490	1.212	0.424	2.436	344
	18.10	0.9460	1.472	0.362	2.439	355

oil. The permittivity values of the oil were measured at low voltage, 750 cycles, by the Anderson bridge method. Fig. 2 also shows the variation of the specific gravities * of these two materials with temperature. It is interesting to note that the corresponding values of permittivity and specific gravity vary

* Thanks are due Mr. J. Dantsizen who made the specific gravity measurements on the compound.

Digitized by Google

in exactly the same way. The gravity curves show that the total expansion of the solidifying cable compound is no greater than that of an oil which remains liquid over the given range of temperature.

The effective a-c. resistivity vs. temperature is shown in Fig. 3, which also shows the d-c. resistivity measured at low voltage under entirely different conditions and several weeks later. The corresponding curves for a special grade compound of the same type, not included in the tables, are also given in Fig. 3.

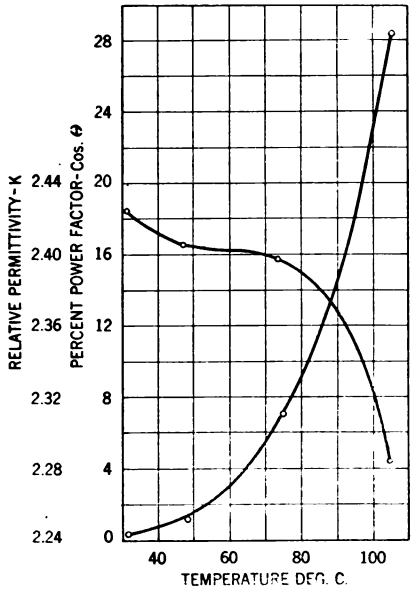


FIG. 1—RELATIVE PERMITTIVITY AND POWER FACTOR OF MINERAL HYDROCARBON BASE CABLE COMPOUND AT 16 KV. PER CM.

The relative difference between the two compounds is approximately the same under the two methods of test, one carefully made with elaborate apparatus, and the other, under entirely different conditions with comparatively simple apparatus. This is important for it supplies an easy way of determining the value of a compound. To appreciate this fully an outline of the two tests is given below.

The a-c. measurements were taken between plane discs spaced one cm. apart with the edge of the grounded plate protected by a guard ring, 1/32 in. (0.794 mm.) spacing between guard ring and

Digitized by Google

plate. The active area was 40 cm. in diameter. Every care was taken to obtain a uniform temperature and shield from all sources of exterior loss.

The d-c. measurements were taken at 500 volts between disks 5 cm. in diameter and spaced 0.33 cm. apart. No guard rings were used and no special precautions were taken to eliminate surface leakage. The spacing was accomplished by placing a small glass rod 0.33 cm. diameter between the disks.

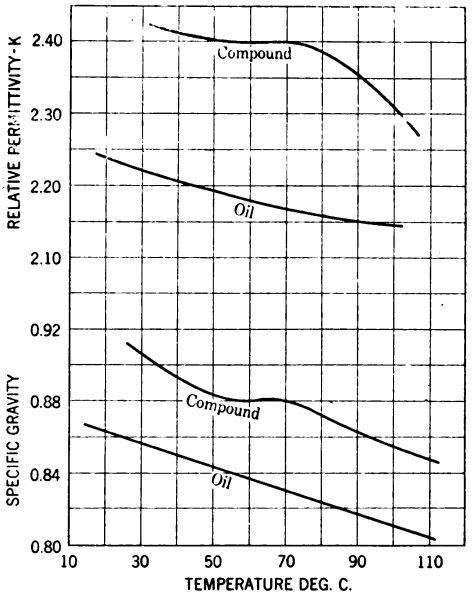


FIG. 2—RELATIVE PERMITTIVITY AND SPECIFIC GRAVITY OF A HEAVY MINERAL INSULATING COIL AND MINERAL HYDROCARBON BASE CABLE COMPOUND

Considering the difference in the methods, the a-c. and d-c. readings check quite closely. Theoretically the d-c. resistance should be slightly the highest. The tests on compound are always started at high temperature so that any moisture that may have been absorbed during exposure to air will be expelled.

SINGLE-CONDUCTOR CABLE

The data given in this paper have become generally known as dielectric energy loss measurements. This is only part of the truth, since all of the electrical constants and characteristics

Digitized by Google

can be calculated for the particular conditions of temperature, frequency, etc., under which they are taken.

The nomenclature and formulas for single-conductor cable as used throughout are given in *Appendix A*.

Data on Single-Conductor Paper Cable

Cable No. 1. The data in Table II were taken on a six-ft. (1.83-m.) length of single-conductor paper-insulated cable,

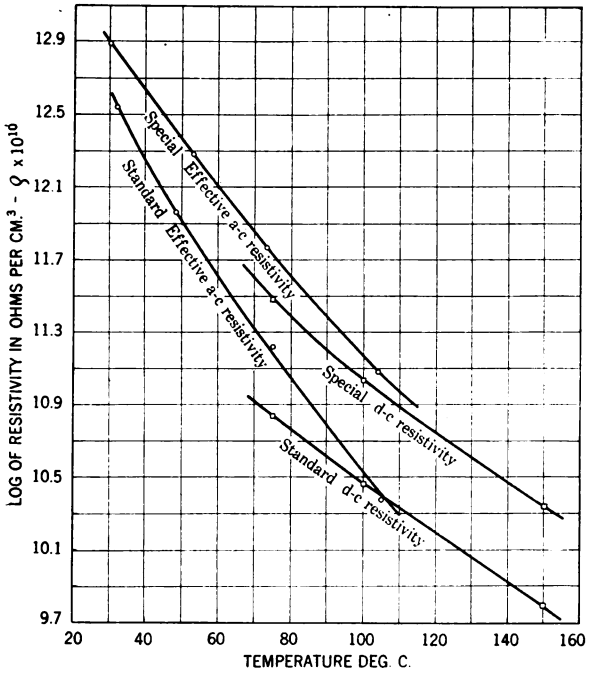


FIG. 3—LOG OF RESISTANCE PER CM.³ OF TWO TYPES OF MINERAL HYDROCARBON BASE CABLE COMPOUND

made up special for test and tested a few weeks after being made. The data on only one 6-ft. sample is given but three, cut from the same length of cable, were tested and checked almost exactly. The specifications were:

2/0 stranded conductor, 0.412 in. (10.45 mm.) max. diameter.

9/32-in. (7.144 mm.) paper, vacuum treated and filled with a mineral hydrocarbon base cable compound.

3/32-in. (2.38-mm.) lead sheath.

Digitized by Google

TABLE II. (CABLE NO. 1)

3/0 single conductor, maximum diameter 0.412 in.
2/32 in. paper filled with mineral hydrocarbon base compound.
9/32 in. lead sheath.
Frequency 60 cycles.

T deg. cent	E 10^3	W/ft.	I/ft. 10^{-3}	P.F. per cent.	C/ft. 10^{-9}	K_{av}	ρ_{av} 10^{10}
25	6	0.00882	0.1455	1.01	0.0645	3.257	91.0
	10	0.0250	0.244	1.024	0.0648	3.280	89.40
	14	0.550	0.344	1.142	0.653	3.300	79.50
	18	0.140	0.445	1.742	0.0651	3.320	51.60
	22	0.308	0.548	2.552	0.0661	3.347	35.00
	26	0.542	0.654	3.19	0.0667	3.377	28.15
	30	0.8125	0.760	3.563	0.0672	3.402	24.50
50	6	0.0450	0.147	5.10	0.0650	3.286	17.82
	10	0.1360	0.246	5.53	0.0651	3.300	16.40
	14	0.280	0.3455	5.79	0.0655	3.312	15.60
	18	0.505	0.448	6.26	0.0660	3.340	14.30
	22	0.837	0.557	6.905	0.0671	3.398	12.89
	26	1.268	0.676	7.22	0.0692	3.485	11.90
75	6	0.214	0.155	23.13	0.0667	3.380	3.76
	8	0.382	0.207	23.30	0.0668	3.382	3.74
	10	0.600	0.259	23.50	0.0669	3.386	3.72
	12	0.883	0.312	23.76	0.671	3.396	3.64
	14	1.218	0.367	24.09	0.675	3.418	3.58
	16	1.646	0.426	24.49	0.0686	3.472	3.48
	18	2.130	0.486	25.05	0.0694	3.515	3.39
100	5	0.292	0.150	39.05	0.0735	3.713	1.982
	7	0.587	0.211	39.78	0.0736	3.720	1.860
	10	1.224	0.304	41.10	0.0738	3.722	1.820
	13	2.127	0.398	41.10	0.0740	3.750	1.775
	14	2.483	0.432	41.10	0.0748	3.790	1.764
	15	2.850	0.468	41.10	0.0752	3.850	1.760
75	6	0.239	0.1585	25.07	0.0682	3.44	3.36
	8	0.432	0.211	25.60	0.0677	3.43	3.33
	10	0.688	0.264	26.07	0.0677	3.43	3.24
	12	1.000	0.318	26.22	0.0680	3.436	3.215
	14	1.378	0.374	26.32	0.0685	3.467	3.18
	16	1.852	0.4333	26.72	0.0694	3.507	3.06
	18	2.412	0.496	27.02	0.0705	3.567	3.00
50	6	0.059	0.147	7.83	0.0650	3.286	11.40
	10	0.211	0.246	8.58	0.0651	3.300	10.58
	14	0.442	0.3455	9.13	0.0655	3.312	9.87
	18	0.805	0.448	9.985	0.0660	3.340	8.96
	22	1.321	0.557	10.27	0.0671	3.398	8.15
	25	1.860	0.646	11.51	0.0692	3.485	7.49
25	6	0.0105	0.1455	1.202	0.0645	3.257	76.40
	10	0.0305	0.244	1.250	0.0648	3.280	73.00
	14	0.0762	0.344	1.582	0.0653	3.300	57.30
	18	0.1935	0.445	2.418	0.0651	3.320	37.40
	22	0.383	0.548	3.175	0.0661	3.347	28.20
	26	0.627	0.654	3.692	0.0667	3.377	24.05
	30	0.934	0.760	4.100	0.0672	3.402	21.50

Digitized by Google

TABLE II. (CABLE NO. 1)—(*Continued*)

2/0 single conductor, maximum diameter 0.412 in.
9/32 in. paper filled with mineral hydrocarbon base compound.
3/32 in. lead sheath.
Frequency 60 cycles.

T deg. cent	E 10^3	W/ft.	I/ft. 10^{-3}	P.F. per cent.	C/ft. 10^{-9}	K_{av}	ρ_{av} 10^{10}
50	6	0.056	0.147	6.35	0.0650	3.286	14.32
	10	0.158	0.246	6.425	0.0651	3.300	14.10
	14	0.331	0.3455	6.84	0.0655	3.312	13.20
	18	0.592	0.448	7.345	0.0660	3.340	12.20
	22	0.960	0.557	7.83	0.0671	3.398	11.24
	26	1.508	0.676	8.59	0.0692	3.485	10.03
75	6	0.238	0.157	25.28	0.0670	3.40	3.38
	8	0.433	0.209	25.90	0.0670	3.40	3.32
	10	0.678	0.2615	25.90	0.0671	3.404	3.28
	12	0.990	0.3155	26.12	0.0673	3.417	3.24
	14	1.367	0.3715	26.28	0.0679	3.447	3.20
	16	1.837	0.4305	26.68	0.687	3.493	3.12
	18	2.410	0.492	27.22	0.0696	3.540	3.00
100	5	0.363	0.164	45.76	0.773	3.920	1.535
	7	0.723	0.230	45.00	0.0778	3.943	1.512
	10	1.484	0.330	44.85	0.0783	3.969	1.500
	13	2.510	0.4323	44.50	0.0784	4.005	1.500
	14	2.910	0.468	44.30	0.0791	4.036	1.500
	15	3.340	0.5055	44.00	0.0804	4.07	1.500
75	6	0.238	0.1605	24.72	0.0688	3.486	3.38
	8	0.428	0.214	25.00	0.0687	3.485	3.33
	10	0.675	0.2673	25.25	0.0686	3.482	3.30
	12	0.980	0.3215	25.41	0.0688	3.486	3.27
	14	1.354	0.378	25.60	0.0692	3.508	3.24
	16	1.820	0.4375	26.00	0.0702	3.553	3.14
	18	2.360	0.500	26.22	0.0712	3.606	3.06
50	6	0.063	0.147	7.15	0.0650	3.286	12.75
	10	0.185	0.246	7.525	0.0651	3.300	12.08
	14	0.371	0.3455	7.672	0.0655	3.312	11.79
	18	0.676	0.448	8.39	0.0660	3.340	10.70
	22	1.144	0.557	9.34	0.0671	3.398	9.44
	26	1.770	0.676	10.06	0.0692	3.485	8.55
25	6	0.0105	0.1455	1.203	0.0645	3.257	76.40
	10	0.0305	0.244	1.250	0.0648	3.280	73.00
	14	0.0725	0.344	1.504	0.0653	3.300	60.40
	18	0.1805	0.445	2.255	0.0651	3.320	40.10
	22	0.3525	0.548	2.923	0.0661	3.347	30.60
	26	0.5825	0.654	3.430	0.0667	3.377	25.90
	30	0.8830	0.760	3.877	0.0672	3.402	22.70

Digitized by Google

The length was immersed in an oil bath. In this way the temperature could be carefully controlled and leakage losses eliminated.

Starting at 25 deg. cent., readings were taken through two complete heat cycles as shown in Table II. The temperature at each step was held constant and watt readings taken every five minutes until constant, (these readings are not given in the table). In this way we were assured of an even temperature through the cross section.

The heat cycle curves in Figs. 4, 5 and 6 show the variation of

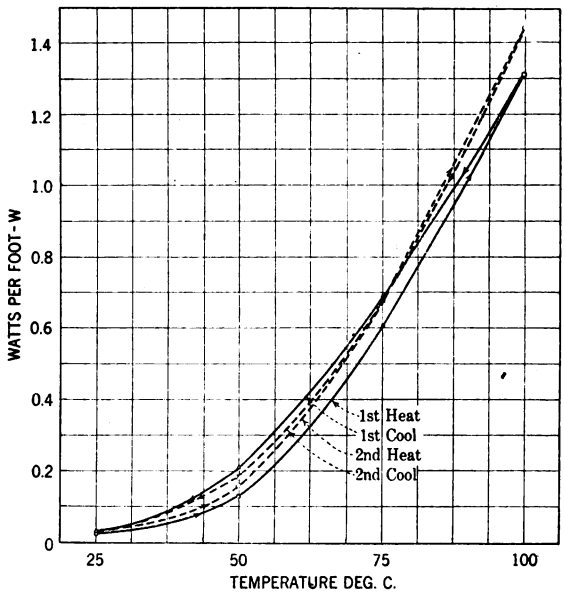


FIG. 4—WATTS PER FOOT CABLE 1 (PAPER) AT 10 KV.

watts, power factor and permittivity with temperature at 10 kv. The loss and permittivity are both higher in the second heat cycle than in the first at temperatures above 70 deg. cent. We can give no clear explanation of this. It is probably due to a combination of things such as, a slight temperature lag, physical and chemical changes and consequent change in the inherent conductivity of the material from the high temperature and voltage stress. (The over-voltage was only left on a few seconds, while the highest points on the curves were being taken and could not have caused an appreciable rise in temperature.) All

Digitized by Google

cable engineers have noted this same characteristic "fatigue" effect in another form when applying a high-potential test to lengths of cable. The d-c. resistivity is much lower just after the

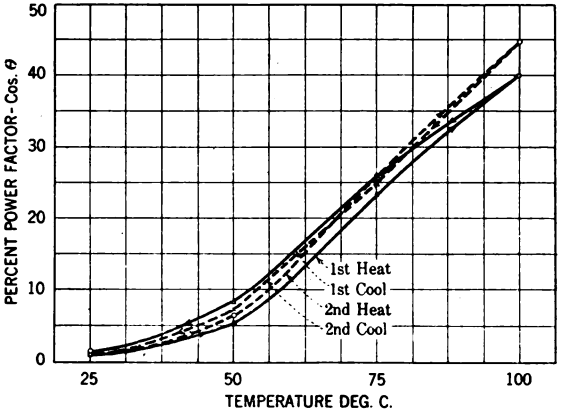


FIG. 5—PER CENT POWER FACTOR CABLE 1 (PAPER) AT 10 KV.

high potential test, and when this is severe it never regains its former value. Middleton and Dawes * gave data on this in a paper read before the Institute in 1914.

S. Evershed * formulated a very interesting theory of moisture

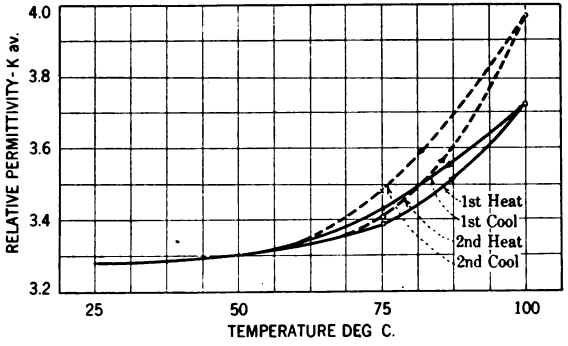


FIG. 6—RELATIVE PERMITTIVITY CABLE 1 (PAPER) AT 10 KV.

conduction in capillary passages which could account for the "heat cycles" and also the increase of the second cycle at higher

* *Voltage Testing of Cables*, by W. I. Middleton and C. L. Dawes, TRANS. A. I. E. E., Vol. 33, p. 1185.

* "The Characteristics of Insulation Resistance" by S. Evershed, *Journal* I. E. E., Vol. 52, 1914, p. 51.

Digitized by Google

temperatures (both effects must be, in truth, caused by the same phenomena). After a careful study of this and many other characteristics of insulating materials we are convinced that Evershed's theory does not entirely account for or fit in with the things noted and which will be given in this paper.

Cable manufacturers have paid a great deal of attention to moisture and developed very effective ways of eliminating it and it does not seem possible that moisture could play an important part in present day cable insulation as long as the lead sheathing remains intact. We have never yet found a case where trouble experienced in operation could be attributed to initial moisture under the above condition. Moisture is sometimes entrapped in cable joints but it does not, as will be shown later, (tests on Cable No. 4), travel along the length of cable to a great extent.

The same characteristic "heat cycles" were experienced with rubber insulated cable sealed in lead sheathing. There was no moisture in this rubber but there was a chemical change due to heating during test. It is chemical instability under temperature and voltage stress that is the predominating question in present day cable insulation problems and not moisture. What is needed is working theory of chemical changes and intermolecular phenomena under high temperature and voltage stress.

The similarity between the watts and permittivity cycles (Figs. 4 and 6) is also worthy of note. This same similarity has been experienced with rubber, varnished cambric and other types of insulation.

For a long time we were puzzled by the erratic behavior of the resistivity vs. voltage curves on paper cable insulation at low temperatures. The 25 deg. cent. curves in Fig. 7 illustrate this peculiar characteristic. At higher temperatures the curves are stable but invariably the room temperature curves behave as shown.

The conclusion was finally reached that this was due to the number of times the samples were bent while cold in preparing them for test. This bending would tend to slightly distort the cross section and cause minute voids or vacuum spaces, which would in a short time be filled with gases from volatilization of the compound. When the cable is again straightened the gases prevent the space being entirely filled up; and, when voltage stress is applied and reaches a value sufficiently high these low-pressure gases are ionized.

Digitized by Google

Referring to Fig. 7 the 25 deg. cent. curves begin to decrease rapidly between 11 and 12 kv., that is, internal ionization begins here. Gradually a point of saturation is reached and the energy consumed by ionization approaches more nearly a true ohmic loss.

The 50 deg. cent. curves are more stable and the 75 deg. and 100 deg. cent. curves entirely so. The specific gravity of the compound alone, Fig. 2, shows that it expands appreciably with

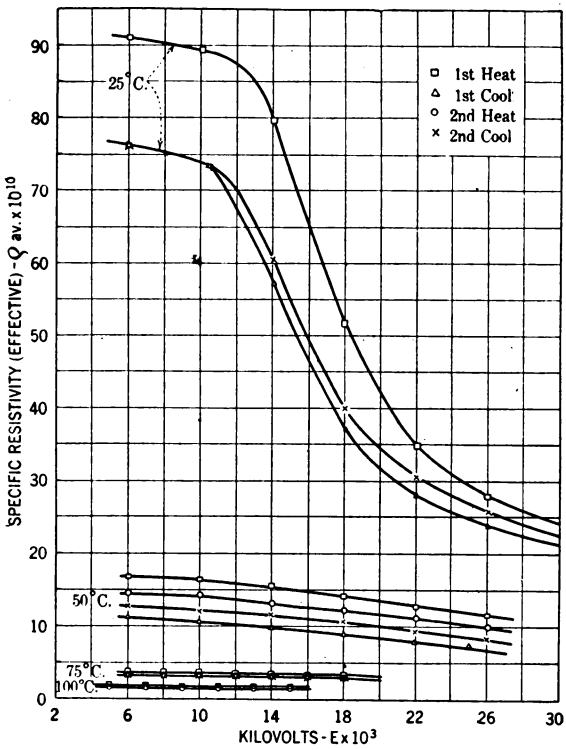


FIG. 7—SPECIFIC RESISTIVITY (EFFECTIVE) CABLE 1 (PAPER)

temperature. The same thing must occur in cables and the small spaces are gradually filled up as the temperature increases, with a corresponding increase in gas pressure. There is still slight ionization at 50 deg. cent. but the inherent loss in the material, itself, predominates. At 75 deg. cent. expansion of the compound has probably reduced these air spaces to an almost infinitesimal size, and in addition, the gas pressure must be so high that ionization is practically eliminated.

Digitized by Google

A test made later on the sample discussed above shows the effects of bending paper cable to small radii while cold. Curve *A* in Fig. 8 was taken at 24 deg. cent. under the same conditions as the 25 deg. cent. curves in Fig. 7, that is, with the length bent U-shape to a radius of 9 in. (22.8 cm.) The length was then wound into a coil having a diameter of 4 in. (10.16 cm.) Curve *B* in Fig. 8 shows that considerably more energy was consumed by ionization and there must, therefore, have been more space to be ionized. It is interesting to note that ionization began at the same voltage in both cases.

An unfilled sample length of cable was made up and the effects of internal ionization studied more closely. This will be discussed later.

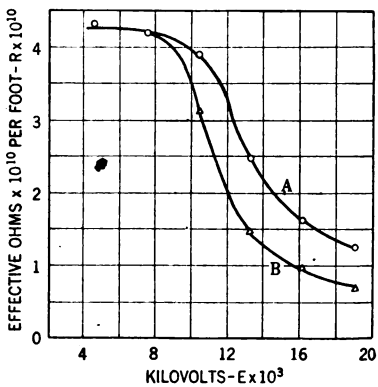


FIG. 8—EFFECT OF BENDING ON INTERNAL IONIZATION AT 24 DEG. CENT. A—BENT TO LARGE RADIUS. B—BENT TO SMALL RADIUS

We have never discovered a case where trouble in operation could be attributed to this low temperature characteristic. Cables used in installation work are handled more carefully than the test samples were and in addition there is little likelihood of continuous internal ionization under operating conditions. The total length of time a cable is operated cold is only a small per cent of its total life and even when the conditions are favorable it is only in cables of small conductor diameter or very high-voltage rating that internal ionization is probable at normal operating voltage. That this ionization must be of a weak nature is evident by the extremely small loss at 25 deg. cent. The same effect has been studied in highly stressed armature coils over long periods of time and it is surprising how little damage internal ionization causes in comparison with external corona at points along the surface of the coil.

Here also, Evershed's moisture theory could be made to apply and even better than in the case of the "heat cycles." The 25 deg. cent. effective a-c. resistivity curves in Fig. 7 have much the same characteristic shape as the d-c. resistivity curves given in his paper. But, Evershed's measurements were taken on

Digitized by Google

materials exposed to air and known to contain appreciable amounts of moisture. The typical d-c. moisture curve drops rapidly from the start and the saturation point is reached at comparatively low-voltage stress, while the a-c. resistivity curve on "dry" materials, that is, materials reasonably free of moisture, do not begin to drop until the materials are well stressed. As the paper progresses other points will be brought out confirming the conclusion that internal ionization accounts for the peculiar shape of these curves.

The rapid decrease in effective resistance and corresponding increase in watts loss with increasing temperature as shown in Figs. 4 and 7 is not due to secondary effects such as moisture or internal ionization of entrapped gases, but is inherent in the material itself and is probably some sort of ionic conduction, with consequent change in the chemical structure. We would naturally expect, then, that the material with the highest effective a-c. resistance at high temperature would be the least liable to deterioration at "hot spots" in a line and is therefore the most desirable one to use.

The power factor at 100 deg. cent. in Fig. 5 is 45 per cent, much higher than any measured on samples of three-conductor cable in which the same materials are used. In looking into this it was found that in making up the short length (30 ft. or 9.1 m.) for test purposes the regular process was not followed as closely as it should have been. The table and curves are given, however, because they are complete and bring out a number of interesting points. Another test length was made up under more favorable conditions and the readings on this are given below.

Cable No. 2. Three samples were cut from the second special length of cable. The readings on these checked very closely and only one will be considered. This same plan was followed throughout in testing lengths of new cable, the samples always checking within three or four per cent. Cable No. 2 was similar in every respect to cable No. 1, except that care was taken to represent the regular three-conductor process more closely.

Only one heat cycle was taken and the values are given in Table III. The resistivity vs. voltage curves are given in Fig. 9. The same characteristics drop in resistivity noted in Cable No. 1 is again in evidence, starting at 12-kv. and reaching saturation at about 26 kv. The resistivity is much higher than that of cable No. 1 and the power factor lower. At 100 deg. cent., as shown in Fig. 10, the power factor is 13.4 per cent and this

Digitized by Google

TABLE III. (CABLE NO. 2)

2/0 single conductor, maximum diameter 0.412 in.
9/32 in. paper filled with mineral hydrocarbon base compound.
3/32 in. lead sheath.
Frequency 60 cycles.

T deg. cent	E $1C^3$	W/ft.	I/ft. 10^{-3}	P.F. per cent.	C/ft. 10^{-9}	$K_{av.}$	$\rho_{av.}$ 10^{10}
22	6.06	0.0040	0.132	0.505	0.0577	2.910	205.6
	8.08	0.00711	0.176	0.500	0.0578	2.915	205.2
	10.00	0.0110	0.2155	0.520	0.0577	2.910	202.5
	15.20	0.0349	0.329	0.696	0.0575	2.895	147.0
	18.10	0.0832	0.392	1.172	0.0575	2.895	87.5
	21.00	0.1970	0.456	2.050	0.0576	2.900	49.8
	25.95	0.6420	0.582	4.240	0.595	2.995	23.3
51	6.06	0.0162	0.136	1.409	0.0584	2.940	70.05
	8.08	0.0205	0.178	1.426	0.0586	2.955	71.0
	10.00	0.0320	0.220	1.454	0.0590	2.969	69.7
	15.20	0.0975	0.336	1.910	0.0586	2.955	52.20
	18.10	0.1850	0.397	2.575	0.0581	2.930	39.40
	21.00	0.3380	0.462	3.480	0.0581	2.930	29.10
	25.95	0.8740	0.590	5.700	0.0625	3.155	17.12
73.5	4.34	0.0241	0.093	6.36	0.0567	2.860	16.90
	6.06	0.0480	0.132	5.92	0.0569	2.868	16.82
	8.08	0.0852	0.175	5.80	0.0568	2.862	16.74
	10.00	0.1340	0.214	5.94	0.0565	2.852	16.60
	12.10	0.1926	0.258	6.10	0.0564	2.840	16.90
	15.20	0.3280	0.325	6.64	0.05645	2.845	15.70
	18.10	0.5200	0.387	7.41	0.05645	2.845	14.00
100	4.34	0.0568	0.097	13.78	0.0589	2.970	7.54
	6.06	0.1094	0.138	13.60	0.0590	2.978	7.46
	8.08	0.1960	0.182	13.50	0.0591	2.980	7 40
	10.00	0.303	0.2255	13.41	0.0591	2.980	7.35
	12.10	0.447	0.272	13.60	0.0591	2.980	7.29
	15.20	0.720	0.342	14.20	0.0591	2.980	7.13
	18.10	1.116	0.408	15.10	0.593	2.985	6.54
73	4.34	0.0254	0.095	6.16	0.0580	2.925	16.50
	6.06	0.0499	0.136	6.14	0.0581	2.930	16.46
	8.08	0.0886	0.177	6.20	0.0581	2.932	16.40
	10.00	0.136	0.220	6.22	0.0584	2.940	16.36
	12.10	0.1990	0.267	6.38	0.0584	2.940	16.32
	15.20	0.3340	0.336	6.78	0.0584	2.940	15.40
	18.10	0.5540	0.400	7.50	0.0585	2.950	13.19
52	6.06	0.02135	0.137	2.57	0.0594	2.995	38.20
	8.08	0.0410	0.181	2.81	0.0594	2.995	37.40
	10.00	0.0600	0.224	2.78	0.0594	2.994	36.70
	15.20	0.1520	0.339	2.95	0.0592	2.980	33.70
	18.10	0.2684	0.405	3.55	0.0594	2.995	27.20
	21.00	0.4580	0.468	4.66	0.592	2.980	21.50
	25.95	1.024	0.594	6.65	0.0605	3.050	14.60
21	6.06	0.00497	0.135	0.607	0.0577	2.912	164.0
	8.08	0.00882	0.179	0.610	0.0580	2.922	165.0
	10.00	0.0139	0.219	0.635	0.0580	2.920	160.5
	15.20	0.0425	0.334	0.837	0.0580	2.920	121.1
	18.10	0.0906	0.397	1.262	0.0581	2.925	80.5
	21.00	0.203	0.462	2.090	0.0581	2.925	48.5
	25.95	0.692	0.590	4.510	0.0604	3.040	21.6

Digitized by Google

corresponds with measurements on samples of similar three conductor cable. We can give no explanation for the peculiar behavior of the permittivity curves in Fig. 10. This is the only

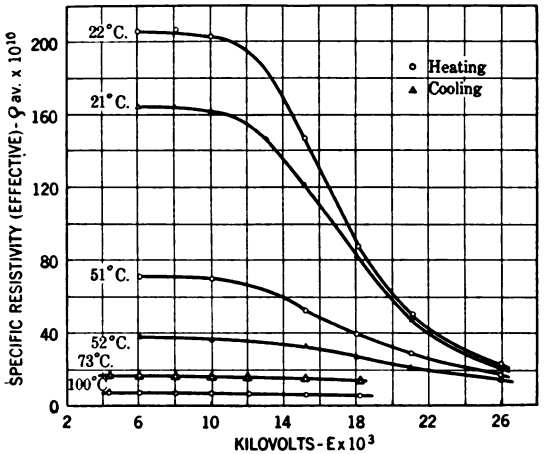


FIG. 9—SPECIFIC RESISTIVITY (EFFECTIVE) CABLE 2 (PAPER)

length of cable that showed a decrease of permittivity with temperature.

Although the high temperature losses and power factors are representative of the materials and process used in making three-

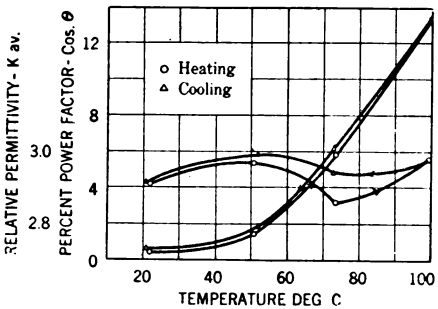


FIG. 10—POWER FACTOR AND RELATIVE PERMITTIVITY CABLE 2 (PAPER) AT 10 KV.

conductor cables, the low-temperature characteristics are not, and indicate that this sample length was not sufficiently well filled with compound. This will be brought out more clearly as the paper progresses.

Digitized by Google

Three-Conductor Cable

It is difficult to measure three-phase dielectric losses in short samples with a reasonable degree of accuracy, and elaborate corrections are necessary. For this reason the measurements on three-conductor cable were taken single-phase. Three-phase values can be approximated from single-phase readings.

Fig. 11 is a cross sectional sketch of a three-conductor cable and also shows the equivalent dielectric circuit. It is assumed that

$$r_1 = r_2 = r_3, r_4 = r_5, = r_6, c_1 = c_2 = c_3 \text{ and } c_4 = c_5 = c_6$$

By applying single-phase voltage to all three conductors and grounding the lead sheath through the instrument, readings can be taken from which r_1 and c_1 can be calculated as shown in Appendix B. In the next set of readings voltage is applied to

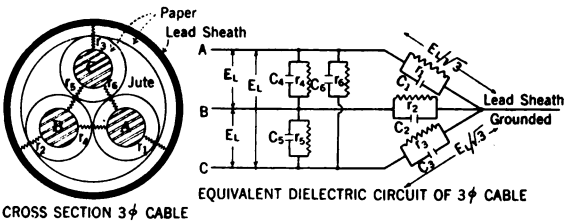


Fig. 11

conductor A, and conductors B and C are connected to the lead sheath. From these readings r_4 and c_4 can be determined. Following the same method the three-phase values can be calculated. The nomenclature and formulas are all given in Appendix B.

Data on Three Conductor Paper Cable

Cable No. 3. This length was cut from an unused reel and was never in service. Specifications are given below:

2/0 three-conductor, max. diameter 0.412 in. (10.45 mm.)
9/32-in. (7.14 mm.) paper on each conductor.
7/32-in. (5.5 mm.) paper over-all.
Filled with a mineral hydrocarbon base compound.
1/8-in. (3.1 mm.) lead sheath.

The test samples each had an active length of lead sheath of 9 ft. (2.7 m.) bent into a half circle with the spread ends

Digitized by Google

properly sealed and immersed in crocks of oil. The whole was placed in a large electrically heated oven.

To be sure that no error was introduced by "end effects" and exterior sources of loss a 20-ft. (6.1-m.) length was first tested at 28 deg. cent. and then cut into 9-ft. (2.6-m.) lengths. The watt readings per foot on the two halves checked within 1.0 per cent of those on the total length.

It required such a long time to reach uniform temperature at each step, (4 to 5 hours, whereas it only required one-half hour in the case of single conductor cable immersed in oil), that a complete heat cycle was not taken but only steps of 28, 48, 74

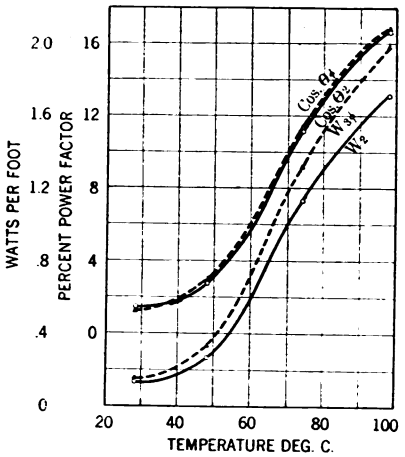


FIG. 12—WATTS PER FOOT AND POWER FACTOR CABLE 3 (PAPER) AT 25 KV.—NEW CABLE, NEVER IN SERVICE

and 98 deg. cent. The calculated single- and three-phase values are given in Table IV. Fig. 12 shows the total calculated three-phase watts ($W_{3\phi}$) and three-phase power factor ($\cos \theta_\phi$) for different temperatures at 25 kv. The corresponding single-phase measurements (W_2 and $\cos \theta_2$), taken by applying high voltage to one conductor and connecting the other two to lead sheath, are also given.

Cos θ_ϕ and cos θ_2 agree almost exactly, and there is a close comparison between $W_{3\phi}$ and W_2. For samples having the same thicknesses of conductors and jacket insulation, $W_{3\phi}$ and W_2 would probably not check so closely but there would still be a good agreement between cos θ_ϕ and cos θ_2, and a study of power factor readings is sufficient; in fact, it is the only practical method

Digitized by Google

TABLE IV. (CABLE NO. 3) NEVER IN SERVICE

2/0 three conductor cable
9/32 in. paper on each conductor
7/32 in. paper overall
1/8 in. lead sheath
Frequency 60 cycles

T deg. cent.	E 10^3	W_1	W_2	$W_{3\phi}$	I_1 10^{-3}	I_2 10^{-3}	$I\phi$ 10^{-3}	$\cos\theta_1$ per cent.	$\cos\theta_2$ per cent.	$\cos\theta\phi$ per cent.	r_1 10^{10}	r_4 10^{10}	r'' 10^{10}	C_1 10^{-9}	C_4 10^{-9}	C'' 10^{-9}	$C\phi$ 10^{-9}
28	10	0.0090	0.0185	0.0262	0.0960	0.160	0.1154	0.937	1.155	1.313	1.11	2.106	0.540	0.0254	0.0085	0.0424	0.0308
	14	0.0169	0.0362	0.0485	0.1300	0.221	0.1549	0.930	1.193	1.290	1.160	2.030	0.542	0.0246	0.0082	0.0410	0.0295
	18	0.0282	0.0605	0.0775	0.1640	0.281	0.1952	0.955	1.227	1.277	1.150	2.007	0.535	0.0242	0.0081	0.0404	0.0287
	22	0.0465	0.0965	0.1170	0.1985	0.341	0.2340	1.064	1.324	1.314	1.041	1.936	0.502	0.0239	0.0080	0.0399	0.0281
	26	0.0783	0.1510	0.1673	0.2325	0.402	0.2725	1.294	1.497	1.364	0.854	1.860	0.447	0.0237	0.0079	0.0396	0.0278
	30	0.1190	0.2210	0.2319	0.2675	0.463	0.3125	1.482	1.650	1.430	0.757	1.760	0.407	0.0236	0.0079	0.0395	0.0276
48	10	0.0162	0.0395	0.0514	0.0970	0.151	0.1024	1.670	2.615	2.905	0.617	0.859	0.253	0.0258	0.0071	0.0400	0.0272
	14	0.0325	0.0785	0.1005	0.1363	0.211	0.1402	1.701	2.630	2.920	0.603	0.852	0.249	0.0258	0.0071	0.0400	0.0272
	18	0.0541	0.1318	0.1704	0.1752	0.272	0.1849	1.712	2.690	2.940	0.598	0.833	0.246	0.0258	0.0071	0.0401	0.0272
	22	0.0834	0.2015	0.2572	0.2140	0.335	0.2266	1.767	2.730	2.970	0.580	0.817	0.240	0.0258	0.0071	0.0401	0.0272
	26	0.1202	0.2880	0.3630	0.2527	0.392	0.2675	1.830	2.820	3.010	0.563	0.807	0.235	0.0258	0.0071	0.0401	0.0272
	30	0.1637	0.3890	0.4879	0.2925	0.452	0.3072	1.865	2.860	3.050	0.550	0.800	0.231	0.0258	0.0071	0.0401	0.0271
74	10	0.091	0.160	0.2055	0.0990	0.154	0.1042	9.20	10.46	11.27	0.1100	0.286	0.0625	0.0259	0.0073	0.0406	0.0275
	14	0.180	0.323	0.3945	0.1390	0.217	0.1479	9.25	10.62	11.02	0.1088	0.274	0.0606	0.0262	0.0073	0.0408	0.0278
	18	0.302	0.548	0.6720	0.1790	0.280	0.1900	9.31	10.87	11.33	0.1071	0.261	0.0592	0.0263	0.0073	0.0410	0.0278
	22	0.465	0.850	1.0185	0.2190	0.342	0.2330	9.66	11.30	11.50	0.1038	0.251	0.0569	0.0263	0.0073	0.0410	0.0279
	26	0.685	1.222	1.4335	0.2580	0.405	0.2780	10.21	11.60	11.35	0.0987	0.242	0.0553	0.0262	0.0074	0.0410	0.0281
	30	0.968	1.735	1.9785	0.2980	0.470	0.3230	10.85	12.30	11.80	0.0932	0.235	0.0518	0.0262	0.0075	0.0413	0.0284
98	10	0.130	0.230	0.2940	0.1000	0.158	0.1073	13.00	14.55	15.80	0.0769	0.200	0.0435	0.0263	0.0075	0.0415	0.0281
	14	0.260	0.487	0.6015	0.1410	0.222	0.1510	13.17	15.63	16.39	0.0753	0.1726	0.0403	0.0264	0.0075	0.0415	0.0282
	18	0.440	0.840	1.0200	0.1810	0.286	0.1951	13.50	16.28	16.73	0.0737	0.162	0.0386	0.0264	0.0075	0.0416	0.0284
	22	0.680	1.280	1.5300	0.2215	0.350	0.2385	13.95	16.62	16.81	0.0712	0.161	0.0377	0.0234	0.0076	0.0416	0.0285
	26	0.990	1.817	2.1405	0.2615	0.415	0.2838	14.56	16.84	16.79	0.0685	0.1534	0.0361	0.0234	0.0076	0.0416	0.0286
	30	1.370	2.580	3.0300	0.3015	0.478	0.3270	15.14	18.00	17.83	0.0656	0.149	0.0349	0.0264	0.0076	0.0416	0.0286

Digitized by Google

of comparing a number of three-conductor samples having different cross-sectional dimensions.

The three-phase calculations in Table IV require entirely too much time so the "two conductor to lead sheath" connection (W_2, $\cos \theta_2$, etc.) was adopted as a standard in testing the other three conductor samples.

The 98 deg. cent. power factor; Fig. 12, is 16.7 per cent while that of cable No. 2, made up by the same process is 13.5 per cent. This is a very fair agreement when it is considered that one is single- and the other three-conductor, and that they represent different batches.

It is to be expected that a single-conductor cable would have a slightly lower power factor than a similar three-conductor cable. Referring to Fig. 13 and assuming a single-phase voltage E impressed between conductor A and the other two conductors, B and C, which are grounded to the lead sheath, the potential at points 2 and 3 would be 0.5 E. The potential at point 1 would be a little above ground, say 0.1 E, then the potential between 2-1 and 3-1 would be 0.4 E. This tangential stress causes a leakage or equalizing current to flow along the surfaces between the paper and jute filler, and thereby adds to the total loss. The value of the excess loss would be determined by the value of the effective a-c. resistance in the surface leakage path. If this is very high, the excess loss will be only a small part of the total, but if it is comparatively low, this loss may be an appreciable part. It is important then, that materials be used here that have the highest possible "surface resistance," especially at high temperatures.

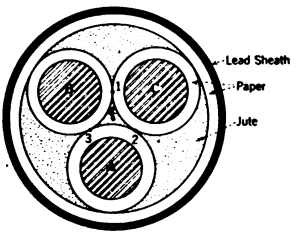


FIG. 13—CROSS SECTION OF THREE-CONDUCTOR CABLE

Three-phase tangential stress between the points 1, 2 and 3 is higher than single-phase, and appears in a different way. Let the three-phase line voltage be E_ϕ. Point 4, being the center of a symmetrical arrangement, will be at ground potential and the potential between this point and conductors A, B and C will be $E_\phi / \sqrt{3}$. An electrostatic polyphase field will rotate about point 4 and M. Höchstadter * has shown by diagrams that, assuming the surface resistance to be high, the difference in potential between the points 1, 2 and 3 is 0.87 E_ϕ.

* "Three Core Cables" by M. Höchstadter, *Electrotechnische Zeitschrift*, Heft 47, 1915. Abstract in the London *Electrician*, 1916, p. 209.

Digitized by Google

The actual three-phase loss will, therefore, be higher than the calculated loss in Table IV (depending upon the value of surface resistance), since the stress between 2-1 and 3-1 will be about twice as great.

These tangential stresses, occurring as they do in the hottest part of the cross section are a weak point in three-conductor cable design and will probably be the limiting feature of the maximum voltage rating that will be reached in the future.

At present 25,000-volt, grounded *Y*, is about the highest rating here in America, where conduit transmission is used. In Germany a 30,000-volt system has been installed *, and one in England, rated at 33,000 volts. † These two systems, however,

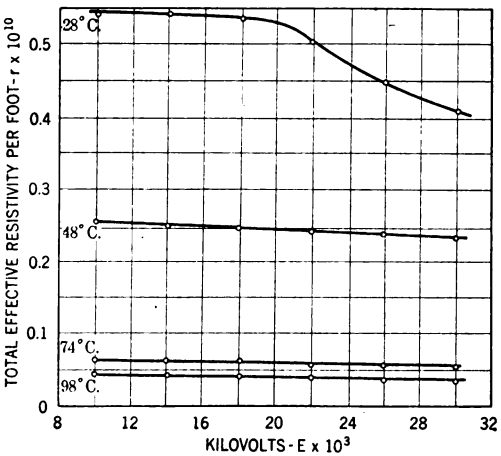


FIG. 14—TOTAL EFFECTIVE RESISTIVITY PER FOOT CABLE 3 (PAPER)

make use of buried cable and operate at relatively low temperatures.

That the present maximum voltage rating for three conductor paper insulated cable in conduits is reliable under reasonable conditions is shown by the experience of one of the operating companies. They have lines rated at 24,000 volts, grounded *Y*, that have been in service continuously for five years and no more trouble has been experienced with these than with lower voltage lines in the same system.

* "30,000-Volt, Three-Phase Cable System, Berlin" by W. Pfaunkuch, E. T. Z., April 18, 1916.

† "Recent Practise in the Manufacture, Laying and Jointing of 33,000-Volt, Three-Phase, Underground Cable" by C. Beaver, London *Electrician*, June 23, 1916.

Digitized by Google

A sample length, cut from one of their lines was obtained and the tests on this are discussed under the following heading

Cable No. 4.

Length of sample, 22 ft. (6.7 m.)
1/0 three-conductor.
9/32-in. (7.1 mm.) paper on each conductor.
7/32-in. (5.5 mm.) paper over-all.
Filled with mineral hydrocarbon base compound.
1/8-in. (3.1 mm.) lead sheath.
In service approximately five years at 24,000 volts.

When preparing this length for test we found that only one end was sealed up. It had evidently been cut from a longer length which was properly sealed when taken from the line and, through an oversight, sealing of the sample omitted. The reel on which this sample was wound had lain out doors in the rain and snow for four weeks after receiving and it was feared that moisture absorption had spoiled it.

Energy loss measurements showed, however, that although this sample had absorbed a slight amount of moisture it did not affect the insulation characteristics to a great extent.

The whole length was first tested at 24 deg. cent. and then cut in halves. The sum of the loss in the two halves checked the total, but the half towards unsealed end had 6 per cent greater loss than the other, thus indicating that it had absorbed the most moisture. Even this amount must have been extremely small for the power factors were quite low.

The single-phase energy-loss data of the half towards the sealed end is given in Table V. Fig. 15 shows the variation of watts and power factor with temperature. At 25 deg. cent. the 25-kv. power factor is 2.3 per cent and at 100 deg. cent. it is 26.3 per cent. The corresponding power factors for new cable of the same kind are 1.9 per cent and 16.7 per cent. (Fig. 12). Allowing for possible variation in different batches, and any slight amount of moisture that may have been absorbed during exposure, this is a good agreement, and together with the operating experience, shows that this type of cable had not deteriorated to an appreciable extent, if at all. After the tests were completed Cable No. 4 was cut open and closely examined. It was found to be in good condition.

The resistivity r'' curves are given in Fig. 16. Internal ionization begins at about 20 kv. in the 24 deg. cent. curve, and there

Digitized by Google

is also a slight break in the 51 deg. cent. curve. The corresponding low temperature (28 deg. cent.) curve of Cable No. 3 (Fig. 14) shows ionization starting at the same voltage, but at 48 deg.

TABLE V. (CABLE NO. 4) IN SERVICE 5 YEARS.

Specifications same as for Cable No. 3 with exception that conductors were 1/0. Frequency 60 cycles.

T deg. cent.	E 10^3	W_2	I_2 10^{-3}	P.F. per cent.	r'' 10^{10}	C'' 10^{-9}
24	10.08	0.0238	0.1420	1.66	0.427	0.0374
	12.92	0.0386	0.1786	1.678	0.430	0.0366
	15.80	0.0584	0.2170	1.705	0.428	0.0363
	18.10	0.0771	0.2480	1.720	0.425	0.0362
	23.10	0.1450	0.3140	1.999	0.368	0.0361
	25.00	0.1850	0.339	2.200	0.338	0.0360
	30.00	0.3230	0.4040	2.670	0.279	0.0357
51	10.08	0.1103	0.1462	7.51	0.0919	0.0385
	12.92	0.1820	0.1859	7.57	0.0916	0.0380
	15.80	0.2700	0.2270	7.46	0.0914	0.0379
	18.10	0.3600	0.2615	7.63	0.0911	0.0379
	23.10	0.5940	0.3300	7.76	0.0900	0.0378
	25.00	0.728	0.3560	8.15	0.0860	0.0377
	30.00	1.129	0.4280	8.77	0.0799	0.0377
74	10.08	0.202	0.1512	13.26	0.0503	0.0396
	12.92	0.334	0.1930	13.39	0.0502	0.0393
	15.80	0.496	0.2340	13.45	0.0501	0.0390
	18.10	0.655	0.2640	13.52	0.0500	0.0384
	23.10	1.063	0.3370	13.70	0.0499	0.0384
	25.00	1.287	0.3670	14.20	0.0487	0.0384
	30.00	1.970	0.4370	15.00	0.0466	0.0384
77	10.08	0.219	0.1512	14.37	0.0472	0.0394
	12.92	0.356	0.1930	14.26	0.0469	0.0392
	15.80	0.528	0.2350	14.31	0.0468	0.0390
	18.10	0.704	0.2670	14.55	0.0466	0.0388
	23.10	1.143	0.3380	14.69	0.0465	0.0384
	25.00	1.400	0.3680	15.18	0.0446	0.0385
	30.00	2.110	0.4400	15.92	0.0426	0.0385
101	10.08	0.463	0.162	28.4	0.0220	0.0408
	12.92	0.740	0.204	28.1	0.225	0.0404
	15.80	1.079	0.248	27.5	0.0231	0.0401
	18.10	1.400	0.283	27.3	0.2034	0.0398
	23.10	2.215	0.360	26.7	0.0241	0.0395
	25.00	2.635	0.392	27.0	0.238	0.0402
	30.00	3.920	0.477	27.4	0.0229	0.0406

cent. there is none at all. Ionization is not very pronounced in either sample.

Trouble Experienced in Operation

The most interesting case encountered was the trouble experienced by another one of the operating companies.

Digitized by Google

Several years ago it installed a considerable length of new cable in its 13,800-volt, Y-connected, grounded-neutral system. It had the following specifications:

4/0 three-conductor.
7/32-in. (5.5 mm.) paper on each conductor.
7/32-in. (5.5 mm.) paper over all.
Filled with vegetable hydrocarbon base compound.
1/8-in. (3.1 mm.) lead sheath.

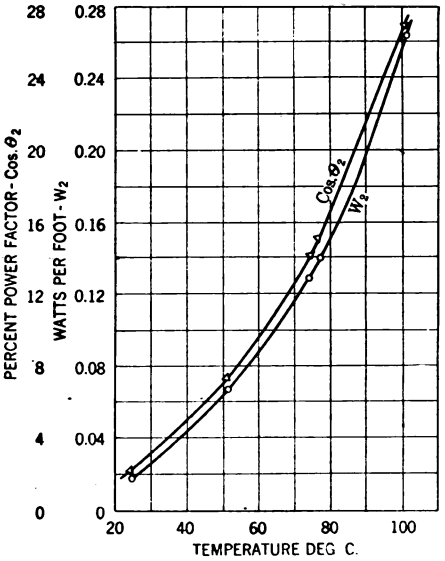


FIG. 15—WATTS PER FOOT AND POWER FACTOR CABLE 4 (PAPER) AT 25 KV.—IN SERVICE FIVE YEARS AT 24 KV.

The failures encountered in this lot of cable gradually increased with time and finally reached such serious proportions that a special investigation was made to determine the trouble.

By referring to the records it was found that the cables had never been heavily overloaded and there were no indications of unusual high-frequency disturbances.

Most of the trouble was experienced at points known to be heated above the average duct temperature from external sources.

The cables were in a number of cases quite warm even when lightly loaded, indicating that the dielectric energy loss must have been so high that it was comparable with copper losses.

Digitized by Google

In one instance, after a cable had failed at a known "hot spot" in the system, sections of the remaining cables at this point were removed from the ducts, cut open and examined.

Referring to Fig. 13, the triangle of jute filler and the surfaces of the paper wrappings between the points 1, 2 and 3 were badly scorched. There were spots in some of the sections where the paper wrappings were charred almost down to the copper. The wrappings next to the lead sheath and those next to the copper (except at the spots where charring was very bad) showed no signs of deterioration and this would indicate that the charring mentioned was not caused directly by burning from overloads or from exterior sources of heat.

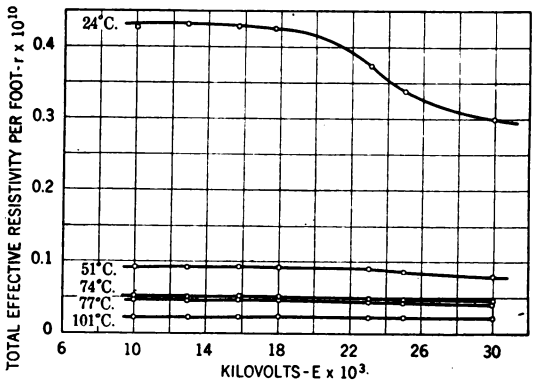


FIG. 16—TOTAL EFFECTIVE RESISTIVITY PER FOOT CABLE 4 (PAPER)

Mr. Höchstadter described this same characteristic charring in the article previously referred to.

By arrangement, whenever failure occurred a sample 12 ft. (3.6 m.) in length was cut from the line near the point of failure, sealed up and sent to the laboratory. Twelve samples were collected in this way and in addition a new one of the same kind was cut from a reel in the store room.

Cable No. 5a. The energy loss data on the new sample referred to above is given in Table VI. As there were so many samples to be tested readings were taken at only two temperatures, 21 deg. and 100 deg. cent.

The power factor and loss curves are given in Fig. 17. The 13,800-volt power-factor is 1.5 per cent at 21 deg. cent. and increases to 54 per cent at 100 deg. cent., showing that this lot of cable had poor temperature characteristics even when new.

Digitized by Google

TABLE VI.

4/0 three-conductor
7/32 in. paper on each conductor
7/32 in. paper over-all
Filled with vegetable hydrocarbon base compound
1/8 in. lead sheath
Frequency 60 cycles

T deg. cent.	E 10^3	W_2	I_2 10^{-3}	P.F. per cent.	r'' 10^{10}	c'' 10^{-9}
			CABLE NO. 5-A NEVER IN SERVICE			
21	4.05	0.00542	0.0860	1.552	0.3025	0.0554
	6.06	0.01187	0.1280	1.529	0.3100	0.0560
	8.89	0.02530	0.1894	1.500	0.3120	0.0566
	11.95	0.04510	0.2550	1.480	0.3150	0.0567
	14.80	0.07145	0.3168	1.522	0.3070	0.0568
	17.88	0.1300	0.3836	1.896	0.2460	0.0569
100	4.05	0.2888	0.1365	52.27	0.00567	0.0763
	6.06	0.6000	0.2020	49.00	0.00614	0.0768
	8.89	1.350	0.2990	50.85	0.00585	0.0769
	11.95	2.555	0.4070	52.50	0.00560	0.0770
	14.80	4.220	0.5170	55.16	0.00519	0.0773
	17.88	6.763	0.6500	58.22	0.00476	0.0784
			CABLE NO. 5-B IN SERVICE 5 YEARS			
22	4.05	0.00864	0.0803	2.655	0.1900	0.0524
	6.06	0.01875	0.1210	2.550	0.1960	0.0527
	8.89	0.0416	0.1787	2.620	0.1900	0.0533
	11.95	0.0899	0.2432	3.095	0.1592	0.0539
	14.80	0.1790	0.3060	3.955	0.1222	0.0549
	17.88	0.3322	0.3750	4.955	0.0963	0.0558
100	4.05	0.947	0.2850	82.10	0.001730	0.1064
	6.06	2.185	0.4400	81.95	0.001684	0.1100
	8.89	4.963	0.6760	82.00	0.001592	0.1157
	11.95	9.55	0.9725	82.15	0.001498	0.1230
	14.80	17.23	1.3700	84.56	0.001272	0.1282
	17.88	30.62	1.9580	87.50	0.001043	0.1402
			CABLE NO. 5-C IN SERVICE 5 YEARS			
29	4.05	0.03925	0.10865	8.90	0.0418	0.0718
	6.06	0.0870	0.1650	8.68	0.0422	0.0720
	8.94	0.1881	0.2412	8.74	0.0423	0.0717
	12.07	0.3673	0.3256	9.35	0.0396	0.0714
	14.93	0.6025	0.4025	10.02	0.0367	0.0711
	18.01	1.0050	0.4935	11.30	0.0321	0.0710
111	4.05	0.9000	0.2900	76.70	0.001825	0.1219
	6.06	1.9940	0.4338	74.50	0.001848	0.1223
	8.94	4.3170	0.6613	73.10	0.001845	0.1314
	12.07	8.5700	0.9350	76.00	0.001699	0.1338
	14.93	14.9100	1.2870	77.70	0.001492	0.1432

Digitized by Google

TABLE VI. (*Continued*)

4/0 three-conductor
7/32 in. paper on each conductor
7/32 in. paper over-all
Filled with vegetable hydrocarbon base compound
1/8 in. lead sheath
Frequency 60 cycles

T deg. cent.	E 10^3	W_2	I_2 10^{-3}	P.F. per cent.	r'' 10^{10}	c'' 10^{-9}
			CABLE NO. 5-E IN SERVICE 5 YEARS			
20	4.05	0.00705	0.0950	1.830	0.2309	0.0622
	6.06	0.01532	0.1440	1.755	0.2421	0.0627
	8.89	0.0322	0.2112	1.715	0.2450	0.0634
	11.95	0.0625	0.2855	1.832	0.2290	0.0640
	14.80	0.1098	0.3550	2.090	0.1995	0.0639
	17.88	0.2110	0.4300	2.747	0.1517	0.0638
100	4.05	0.3546	0.150	58.30	0.00462	0.0797
	6.06	0.747	0.225	54.80	0.00493	0.0844
	8.89	1.516	0.333	51.25	0.00521	0.0854
	11.95	2.842	0.450	52.80	0.00503	0.0849
	14.80	4.450	0.559	53.75	0.00493	0.0842
	17.88	6.840	0.677	56.50	0.00468	0.0816

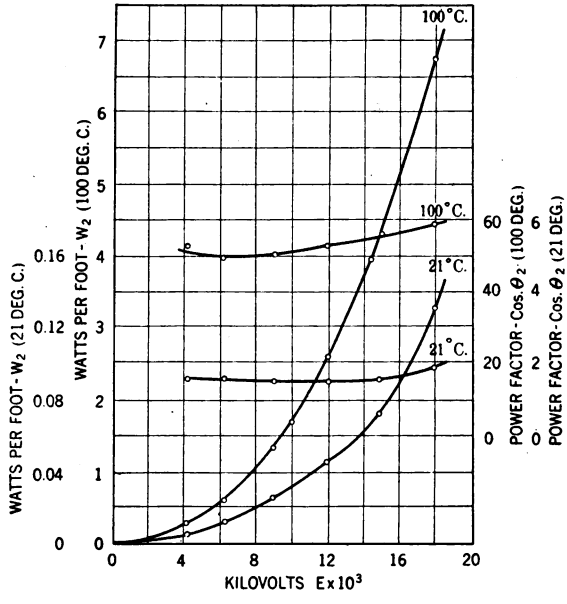


FIG. 17—WATTS PER FOOT AND POWER FACTOR CABLE 5a (PAPER)—NEW CABLE, NEVER IN SERVICE

Digitized by Google

This is an important point and it is safe to say that any new cable with such a high power-factor at 100 deg. cent. will in time cause trouble at "hot spots."

Cable No. 5b. The measurements on this sample, one of those cut from a line near point of failure, are also given in Table VI. The 13,800-volt power-factor in Fig. 18 is 3.7 per cent at 22 deg. cent. and increased to 85 per cent at 100 deg. cent. It was thought that this sample must have been partly broken down and charred to give such an extremely high power-factor at 100 deg.

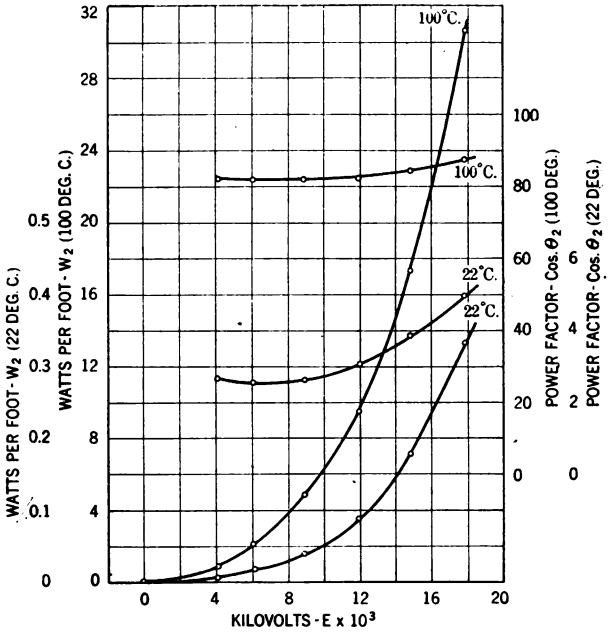


FIG. 18—WATTS PER FOOT AND POWER FACTOR CABLE 5b (PAPER)—IN SERVICE FIVE YEARS

cent., although the 22 deg. cent. power-factor is within reasonable limits. But, when it was cut open no burning or scorching of any kind was found. It was well filled with compound and the surface of the paper between the points, 1, 2 and 3 (Fig. 13) showed evidence of trouble just beginning. The compound had coagulated here, a characteristic sign of distress. One other sample checked the above one closely in every detail.

Cable No. 5c. The data and curves in Table VI and Fig. 19 show this sample to be either saturated with moisture or partly

Digitized by Google

broken down. The 13,800-volt power-factor at 29 deg. cent. is 10 per cent. No insulation gives power factors this high at low temperature unless conducting impurities are present. The 111 deg. cent. power-factor is 77 per cent, not quite as high as that in Cable No. 5*b*.

When cut open three spots, each about one foot in length were found where the characteristic charring of the central section had eaten almost down to the conductors. In the rest of the

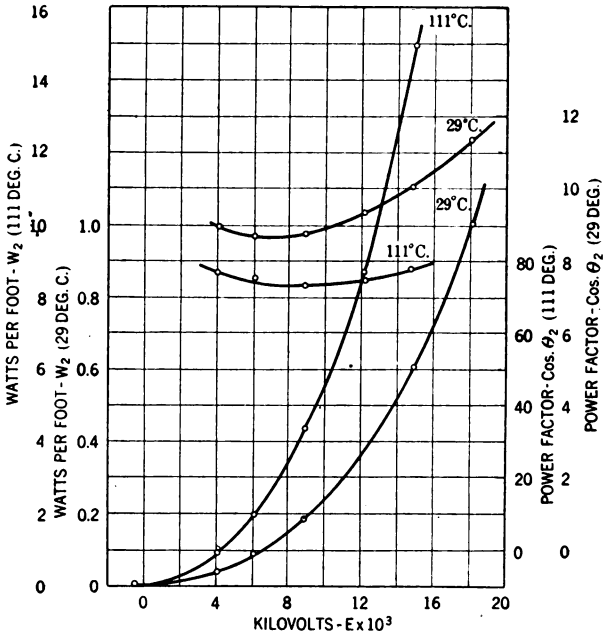


FIG. 19—WATTS PER FOOT AND POWER FACTOR CABLE 5c (PAPER)—IN SERVICE FIVE YEARS

length this section was either scorched or the compound had coagulated as previously described.

Cable No. 5d. The energy loss readings on this length checked those on cable No. 5*c* very closely and are therefore not given in the table. They indicated that the sample was partly broken down, so an endurance run at 15 kv. and 100 deg. cent. was made to get some idea in regard to how a cable actually fails in operation. A log of this run is given in Fig. 20. It is interesting to note that it required two hours and 40 minutes to reach complete breakdown.

Digitized by Google

Examination showed the same characteristic charring at four places. One of these had charred completely through to the conductors, (the point where break down occurred.) It is probable that the endurance run had little to do with the damage at the other spots. It requires a number of days to cause such complete carbonization in an air tight cross section, as we have often observed in aging tests at 200 deg. cent. on different kinds of materials.

Cable No. 5e. The energy-loss data are given in Table VI. The 13,800-volt power factor is 2 per cent at 20 deg. cent. and

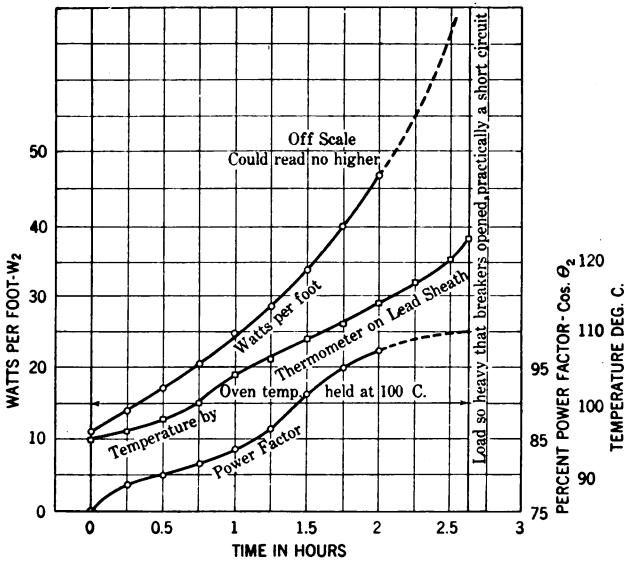


FIG. 20—ENDURANCE RUN, CABLE 5d (PAPER)—IN SERVICE FIVE YEARS

53 per cent at 100 deg. cent. thus comparing with the new sample, (No. 5*a*). This sample (5*e*) had the lowest power factor and losses of any of the old samples tested.

When cut open it was found that the greater part of the length was comparatively "dry," that is, only partly filled with compound. No signs of deterioration were in evidence.

Several of the samples were in this "dry" condition and in none of these were there signs of deterioration, in addition the power factor was always lower than in the well filled samples. This indicates better than anything else, that the compound

Digitized by Google

filler was at fault, and that no moisture was present, for moisture would naturally accumulate in the "dry" sections.

Resistivity Curves.—The low temperature resistivity curves r'' are shown in Fig. 21. The voltage was not carried up to complete saturation in any case. It was necessary to avoid over-stressing and thereby be sure that the samples when examined after test were in the same condition as when cut from the line. Ionization started at 9 kv. in all the samples except the new one (5*a*).

Variation of Capacity with Temperature. A study of the capacity C'' values in Table VI shows that there is considerable increase at high temperatures and that this increase is greater the higher the loss in the sample; in other words, the lower the resistance of the material the higher the capacity. At zero resistance the capacity would be infinity.

Tests on the Compound. Compound was pressed from one of the lengths that had been in service, and a short section of the new length (5*a*). Neither length had been given an electrical test and they remained sealed until ready for the extraction of compound.

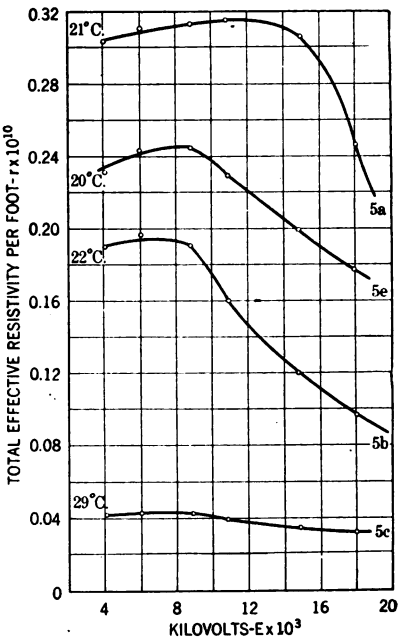


FIG. 21—TOTAL EFFECTIVE RESISTIVITY PER FOOT CABLES 5a, 5b, 5c, 5e (PAPER)

Vacuum treatment gave no evidence of an appreciable amount of moisture in the compound. A chemical analysis showed the presence of free organic acid and this was more marked in the compound which had seen service.

The d-c. resistivity at different temperatures, taken between 5 cm. terminals as described in the first part of the paper, is given in Fig. 22. The resistance of both is very low and that of the old sample shows considerable deterioration, which must be due to chemical change under the conditions of voltage stress and temperature met with in operation.

Digitized by Google

Varnished Cambric and Rubber Insulated Cable

Numerous tests have been made on different kinds of varnished cambric and rubber insulated cable as well as paper insulated cable other than those already discussed.

Space will allow the characteristics of varnished cambric and rubber insulation to be dealt with but briefly. Later we hope to present results showing the value of energy-loss measurements in determining different grades of rubber.

Representative samples of 2/0 single conductor cable having

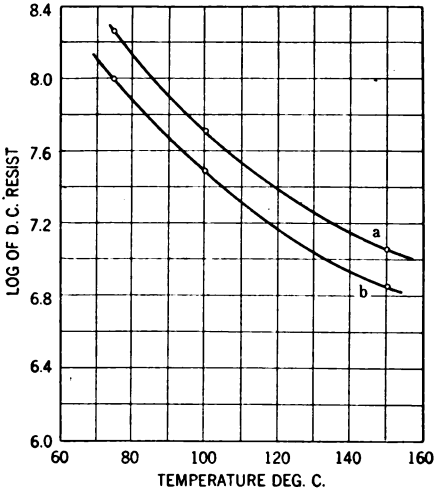


Fig. 22—Log D-C. Resistivity of Two Cable Compounds from Cables in Groups 5. A—From New Cable Never in Service. A—From Old Cable in Service 5 Years

varnished cambric and rubber insulation have been selected for comparison with paper cable as follows:

Cable No. 6. 9/32-in. (7.1 mm.) black varnished cambric.

Cable No. 7. 9/32-in. (7.1 mm.) 33 per cent pure grade para rubber.

Cable No. 8. 9/32-in. (7.1 mm.) 30 per cent good commercial grade rubber compound.

The permittivity and resistivity values of these samples are included in Figs. 24 to 27 which will be discussed under the following headings.

Digitized by Google

Relative Permittivity and Grading

It would perhaps be well to combine the three standard types of cable insulation in one group and study their relative characteristics more closely.

Variation of Permittivity with Voltage Stress. The voltage gradient curve for the cross section of single-conductor cable considered is given in Fig. 23 at a total impressed voltage, E = 10 kv.

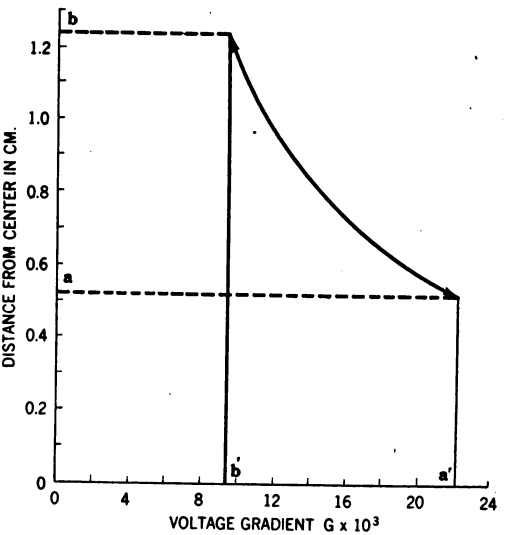


Fig. 23—Voltage Gradient at 10 Kv. for 2/0 Single-Conductor Cable—9/32 in. Thickness of Insulation

$$g = \frac{de}{dx} = \text{voltage gradient}$$

$g_{max.}$ = maximum gradient (a, next to conductor)

g_{av} = average gradient.

The relative permittivity values, K_{av}, in Tables II and III show that K_{av} varies slightly with voltage E. It is evident, then, that K varies with g through the thickness of insulation, and K_{av} represents the value of K at a point approximately coinciding with g_{av}.

In Fig. 24 the 50 deg. cent. values of K_{av} for the different materials are plotted against g_{av} instead of E. The section of the curves between the perpendicular lines shows the variation of K with g through the thickness. The largest variation occurs

Digitized by Google

in Cable No. 8 (rubber) and is only 1.6 per cent. The variation in Cable No. 6 (varnished cambric) is 0.7 per cent. The actual value of g_{max} will therefore be slightly less than the theoretical value given in Fig. 23; in other words, the insulation tends to grade itself automatically, but only to a slight extent.

The above grading of K considers a uniform temperature. In operation, the distribution of temperature will cause still

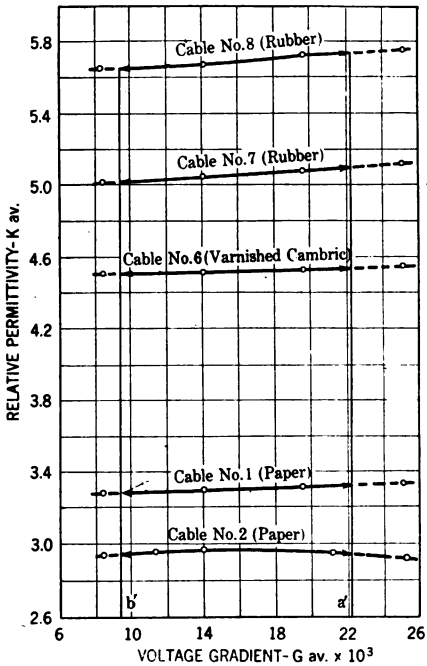


FIG. 24—RELATIVE PERMITTIVITY OF DIFFERENT MATERIALS AT 50 DEG. CENT. AND 10 KV.

further grading, since K increases with temperature in most materials.

Variation with Temperature. Fig. 25 shows the change in K_{av} with temperature for the different materials at $E = 10$ kv. The slope of the varnished cambric curve (Cable No. 6) is very noticeable. The K of good paper insulation (Cable No. 2) does not increase much with temperature but that of medium paper (Cable No. 1) increases appreciably above 75 deg. cent. An idea of the rapid increase of K with temperature in poor paper insulation can be obtained from the capacity c'' values in Table VI.

Digitized by Google

Assume that the conductor is at a temperature of 50 deg. cent. and the lead sheath 40 deg. cent. Referring to Fig. 25, the largest variation of K, 4 per cent, occurs in varnished cambric (Cable No. 6).

Combining the automatic grading due to voltage stress and that due to temperature the total effect in Cable No. 6 will cause approximately a 3 per cent decrease in g_{max}. In other words, automatic grading is hardly appreciable and the theo-

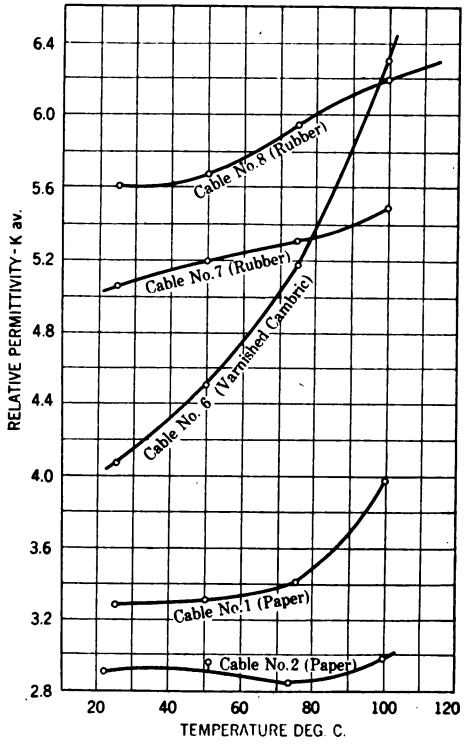


FIG. 25—RELATIVE PERMITTIVITY OF DIFFERENT MATERIALS AT 10 KV.

retical gradients in Fig. 23 are approximately correct. The 3 per cent decrease in g_{max} discussed above is probably entirely neutralized by the distortion at the surface of stranded conductors tending to raise g_{max} slightly above the theoretical value.

EFFECTIVE RESISTIVITY

Variation with Temperature. The 10-kv. curves of effective specific resistivity versus temperature for the different cable samples are given in Fig. 26.

Digitized by Google

A comparison of the slope of these curves shows that paper insulation has the poorest temperature characteristics and must be of the highest grade to bring the 100 deg. cent. resistivity well up in value (Cable No. 2). The resistivity of Cable No. 1, a medium sample, drops very rapidly with temperature and it can be imagined how rapidly the resistivity of a *very* poor cable, such as No. 5b, will drop. It is this effect at "hot spots" that is of such great importance in cable work.

Varnished cambric follows after paper and it is evident that the resistivity characteristics are not particularly good. Var-

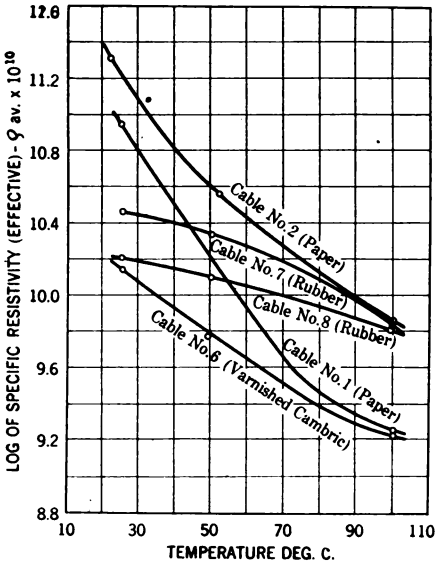


FIG. 26—LOG OF SPECIFIC RESISTIVITY (EFFECTIVE) AT 10 KV.

nished cambric has this advantage, though; it is very stable and uniform. Its good mechanical qualities are another point in its favor.

Rubber has the best temperature characteristics. It is to be regretted that these cannot be better utilized, but the physical changes that take place in rubber prohibit its use at high temperatures.

Variation with Voltage Stress. The variation of ρ through the thickness should be dealt with in the same way as the variation of K.

In Fig. 27 the 50 deg. cent. values of ρ_{av} for the different

Digitized by Google

samples are plotted against g_{av} instead of E. The section of the curves between the perpendicular lines shows the variation of ρ with g through the thickness. The greatest variation, 26 per cent, occurs in Cable No. 8, and the least, 8 per cent, in Cable No. 6.

Referring again to Fig. 26 and assuming temperatures of 50

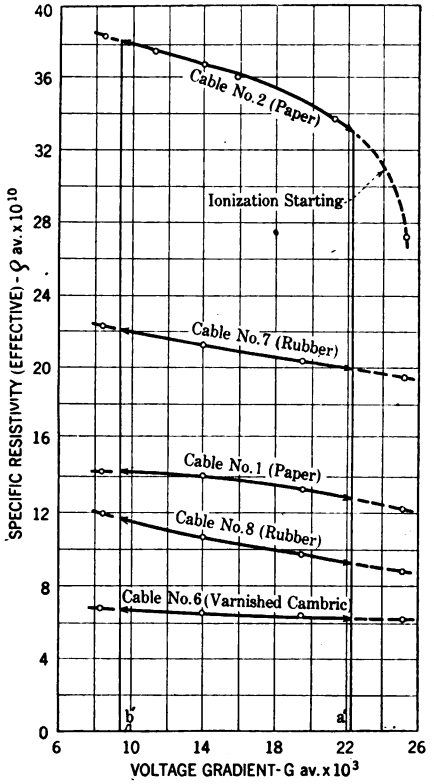


FIG. 27—SPECIFIC RESISTIVITY (EFFECTIVE) AT 50 DEG. CENT. AND 10 KV.

to 40 deg. cent. for the conductor and lead sheath respectively, the greatest variation of ρ through the thickness, 50 per cent occurs in Cable No. 1, and the least, 5 per cent in Cable No. 7.

When the above two effects are combined it is evident that the value of f is much less, and consequently the watts per cm.^{3} next to the conductor is much more, than the values further out in the thickness.

Digitized by Google

Internal Ionization

As mentioned in the first part of the paper, coils have been overstressed for long periods of time and the effects of internal and external ionization noted. Examination, after a continuous run of a year or more at two times normal operating voltage, shows deposits on the walls of the gas spaces; but it is surprising how little actual damage is done. The materials used, however, were known to be quite stable chemically.

Overstressing to a point where internal ionization begins is, of course, to be avoided in practise; it is obvious however, that materials should be used that are chemically the least affected

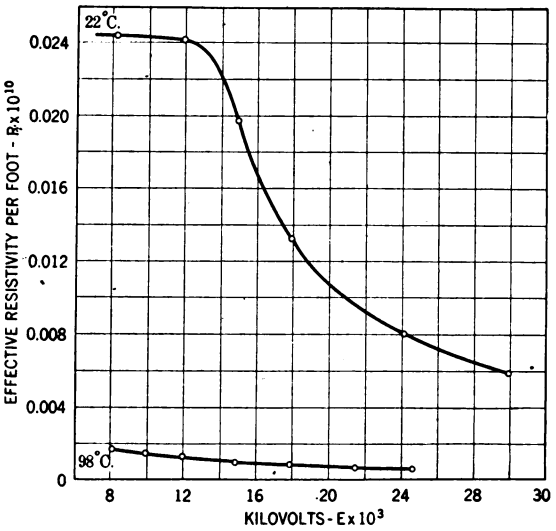


Fig. 28—Internal Ionization in a High-Voltage Armature Coil

by it, for ionization may sometimes be met with; for instance, when high-potential test is applied to lengths of cable in low temperature conduits.

Fleming and Johnson* have dealt to some length with the effects of internal ionization in overstressed coils insulated with chemically unstable materials. They found these effects very harmful in some cases.

The resistivity curves of an armature coil whose thickness of main insulation, (0.22-in. or 5.6 mm.) was known to contain small

*Chemical Action in the Windings of High-Voltgage Machines", by Fleming and Johnson, *Journal* I. E. E., Vol. 47, p. 530.

Digitized by Google

gas spaces are given in Fig. 28. The ionization at 22 deg. cent. starts at 12 kv. and is quite pronounced.

Ionization in Unfilled Cables. Special lengths of cable (Nos. 9a and 9b) were made up for the purpuse of studying internal ionization.

The specifications are as follows:

2/0 single conductor
9/32 in. (7.1 mm.) varnished paper tape.
3/32 in. (4.7 mm.) lead sheath.

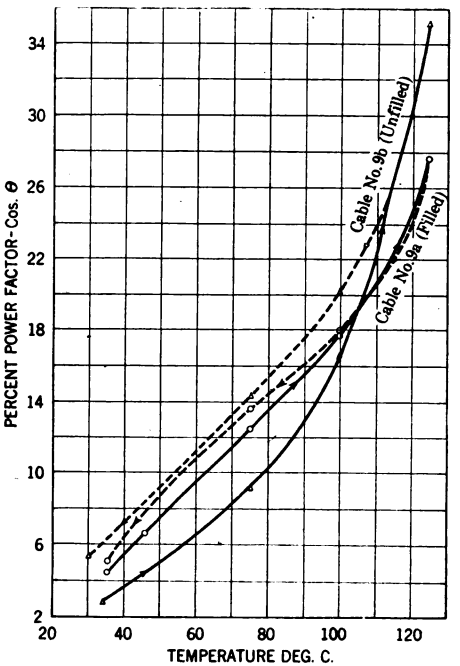


FIG. 29—PER CENT POWER FACTOR CABLES 9a AND 9b (VARNISHED PAPER) AT 10 KV.

The tape in No. 9a was first run through compound and then applied half lap. Compound was copiously used and a thoroughly filled insulation resulted. The tapings in No. 9b were applied dry without filling of any kind, thus leaving small air spaces between layers at the overlapping edges of the tape.

Three samples of Cable No. 9a were tested and checked exactly. None of the four No. 9b samples checked and one broke down at 24 kv. while taking readings. The No. 9b curves given are for the average sample.

Digitized by Google

Fig. 29 shows the 10-kv. power factor heat cycles. That of No. 9a is very stable but there is a big difference between the heating and cooling curves of No. 9b. The permittivity cycles

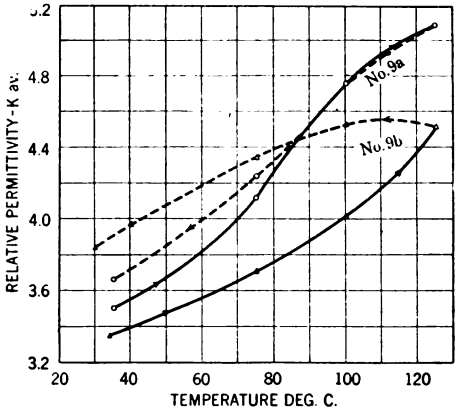


FIG. 30—RELATIVE PERMITTIVITY CABLES 9a AND 9b (VARNISHED PAPER) AT 10 KV.

in Fig. 30 show much the same characteristics. Some very appreciable change must have taken place in No. 9b during the cycle.

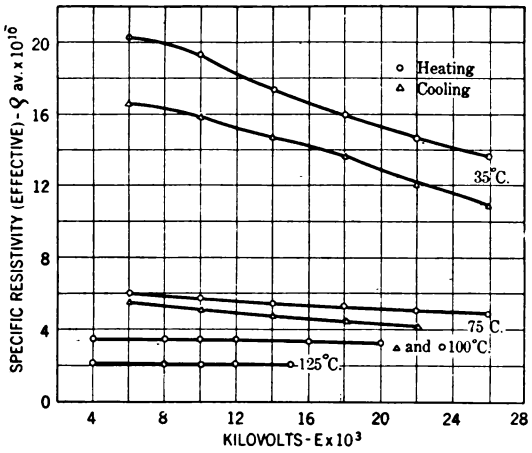


FIG. 31—SPECIFIC RESISTIVITY (EFFECTIVE) CABLE 9a (VARNISHED PAPER, FILLED)

The resistivity curves of No. 9a are given in Fig. 31. The inherent resistance decreases noticeably. There are only traces of ionization in the 35 deg. cent. curves.

Digitized by Google

The corresponding curves for No. 9b in Fig. 32 show pronounced ionization in all of the heating curves, beginning at 6 kv. It has almost entirely disappeared in the cooling curves. The permittivity values in Fig. 33 and 34 follow the same characteristics in an even more pronounced way.

From the general trend of the test it was evident that some sort of partial breakdown occurred in Cable No. 9b at 125 deg.

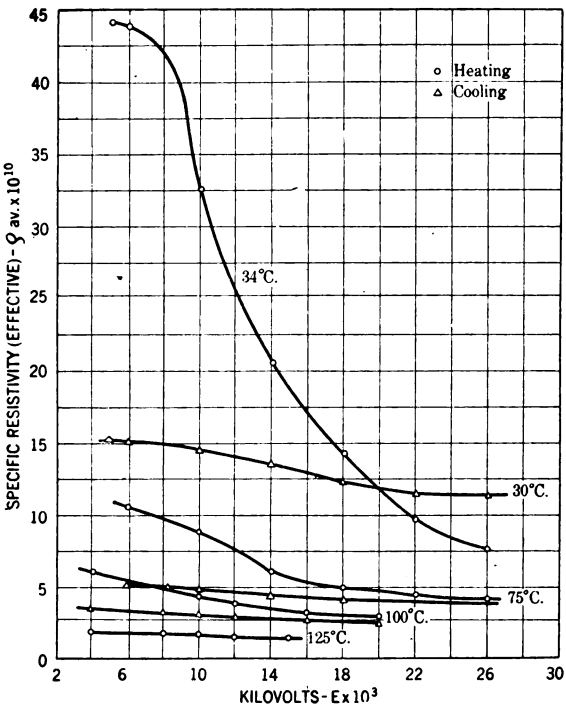


FIG. 32—SPECIFIC RESISTIVITY (EFFECTIVE) CABLE 9b (VARNISHED PAPER, UNFILLED)

cent., so it was cut open for examination. The wrappings especially those nearest the conductor, were perforated with small "pin pricks" in a distinct way. The majority of them followed a straight line lengthwise down the middle of the taping where the adjacent overlapping edge had been in contact.

The air space along this line was ionized and since ionized gas is a good conductor it acted like a sharp metallic edge, that is,

Digitized by Google

concentrated the stress to such a degree that partial failure occurred. Osborne* first noted this characteristic perforation.

The walls of the perforations must have been conducting and

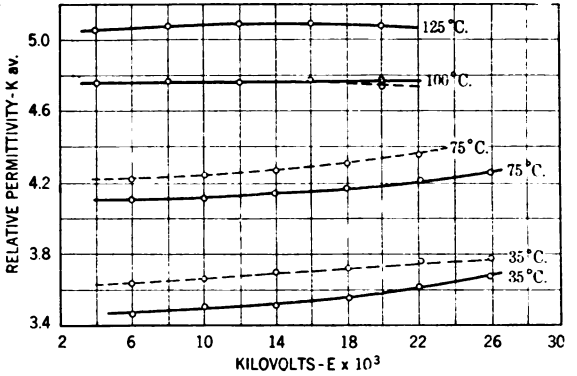


FIG. 33—RELATIVE PERMITTIVITY CABLE 9a (VARNISHED PAPER, FILLED)

this tended to short-circuit the air spaces, for Figs. 32 and 34 show that they were eliminated in some such way in the cooling curves.

The permittivity characteristics in Fig. 34 are of particular

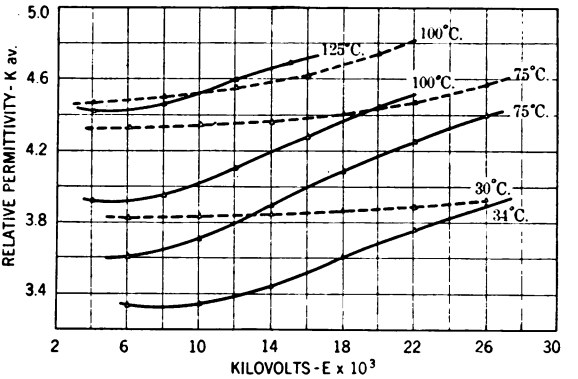


FIG. 34—RELATIVE PERMITTIVITY CABLE 9b (VARNISHED PAPER, UNFILLED)

interest. They illustrate step by step what happened. In the 34 deg. cent. heating curve the effective permittivity increases

Potential Stresses of Dielectrics by H. S. Osborne, PROC. A. I. E. E., Vol. 29, p. 1553.

Digitized by Google

with voltage stress as the low permittivity air spaces are gradually ionized, in other words, eliminated from the effective permittivity. In the 30 deg. cent. cooling curve the air spaces have been short-circuited by perforation at 125 deg. cent. and consequently the curve does not depend upon voltage stress but is almost flat, meeting the 34 deg. cent. heating curve at 27 kv.

It would be interesting to determine at various pressures and spacings the stress necessary to ionize the gases filling spaces in different kinds of insulation, and see if it is not possible to predetermine by calculation the starting point of internal ionization. This would furnish very useful information to designing engineers regarding the proper voltage rating of their apparatus. The investigation is still in its first stage, however, and eventually it is hoped to reach this point.

Acknowledgment. In closing we wish to express our apprepreciation and thanks to Dr. C. P. Steinmetz and J. L. R. Hayden for their interest and able advice; the operating companies who placed at our disposal the opportunity to study cable from their lines; Mr. J. J. Matson for his invaluable assistance in preparing this paper; and Messrs. H. R. Summerhayes and E. W. Hawley whose cooperation was of great help.

APPENDIX A

Showing Method Used in Calculating Single Conductor Cable Data

The following nomenclature and formulas are used throughout the paper:

Let E = impressed voltage
I = total amperes per foot length of cable
W = watts loss (dielectric) per foot length of cable
$\cos \theta$ = dielectric power factor
C = capacity in farads per foot.
$K_{av.}$ = relative permittivity (average through thickness)
K_a = capacity per cm³. of air = 0.08842×10^{-12} farads
R = total effective a-c. insulation resistance per foot.
$\rho_{av.}$ = effective resistance per cm³. (average through thickness)

$$g = \frac{de}{dx} = \text{voltage gradient.}$$

$g_{av.}$ = average voltage gradient through thickness
l = length in cm. = 1 ft. = 30.48 cm.

Digitized by Google

b = radius in cm. inner side lead sheath
a = " " " of conductor.

The dielectric circuit is considered as a parallel circuit, that is, the resistance and capacity are considered as being in parallel.

$$\cos\theta = \frac{W}{E\,I} \tag{1}$$

$$C = \frac{I\sin\theta}{2\pi f E} \tag{2}$$

For a single conductor cable in which the thickness of insulation consists of one kind only:

$$\frac{1}{d\,c} = d\,s = \frac{1}{K_a\,K_{av.}}\cdot\frac{d\,x}{2\,\pi\,l\,x}$$

therefore:

$$C = \frac{k_a\,k_{av.}\,2\,\pi\,l}{\log_e b/a}$$

$$\frac{I\sin\theta}{2\pi f E} = \frac{k_a\,k_{av.}\,2\,\pi\,l}{\log_e b/a}$$

therefore:

$$K_{av.} = \frac{I\sin\theta\cdot\log_e b/a}{(2\,\pi)^2\,l\,f\,E\,K_a} \tag{3}$$

$$d\,R = \rho_{av.}\,\frac{d\,x}{2\,\pi\,l\,x}$$

$$R = \frac{\rho_{av.}}{2\,\pi\,l}\log_e b/a = \frac{E^2}{W}$$

therefore:

$$\rho_{av.} = \frac{2\,\pi\,l\,E^2}{W\log_e b/a} \tag{4}$$

For the voltage gradient:

$$g = \frac{d\,e}{d\,x} = \frac{C\,E}{K_a\,K_{av.}\,2\,\pi\,l\,x}$$

Digitized by Google

therefore:

$$g = \frac{E}{x \log_e b/a} \tag{5}$$

A = area of gradient curve between a and b

$$A = \int_a^b g\,dx = \frac{E}{\log_e b/a} \int_a^b \frac{dx}{x}$$

threrfore: Area, $A = E$ (6)

$$g_{av.} = \frac{E}{b-a} \tag{7}$$

APPENDIX B

Showing Method Used in Calculating Three Conductor Cable Data

Referring to Fig. 11 it is assumed that,

$r_1 = r_2 = r_3$, $r_4 = r_5 = r_6$, $c_1 = c_2 = c_3$ and $c_4 = c_5 = c_6$

For Singlephase Readings:

Let E = variable test voltage
W_1 = loss due to r_1 per foot
W_2 = loss due to r_1 r_4 and r_6 per foot
W_3 = loss due to r_4 per foot
I_1 = current due to Y_1
I_2 = current due to Y_1 Y_4 and Y_6
I_3 = current due to Y_4
$c'' = 2\,c_4 + c_1$ = capacity in farads per foot.

$$r'' = \frac{r_1 r_4}{2\,r_1 + r_4} = \text{effective resistance in ohms per foot.}$$

By applying high voltage to all three conductors connected together and grounding lead sheath through the instrument readings of 3 W_1 and 3 I_1 can be taken at voltages, E, and curves plotted. In the next set of readings high voltage is applied to conductor A and conductors B and C are connected to the lead sheath. These readings correspond to W_2 and I_2.
Then

$$\cos\theta_1 = \frac{W_1}{E\,I_1} = \text{power factor from conductor to lead sheath.}$$

$$\dot{I}_1 = I_1 \cos\theta - j\,(I_1 \sin\theta)$$

Digitized by Google

$$r_1 = \frac{E^2}{W_1} \text{ and } c_1 = \frac{I_1 \sin \theta_1}{2 \pi f E}$$

$$\cos \theta_2 = \frac{W_2}{E I_2} = \text{power factor due to } Y_1 \; Y_4 \text{ and } Y_6$$

$$\dot{I}_3 = \frac{\dot{I}_2 - \dot{I}_1}{2} \text{ and } W_3 = \frac{W_2 - W_1}{2}$$

$$I_3 = 1/2 \sqrt{(I_2 \cos \theta_2 - I_1 \cos \theta_1)^2 + (I_2 \sin \theta_2 - I_1 \sin \theta_1)^2}$$

$$\cos \theta_3 = \frac{W_3}{E I_3} = \text{power factor between conductors.}$$

$$r_4 = \frac{E^2}{W_3} \text{ and } c_4 = \frac{I_3 \sin \theta_3}{2 \pi f E}$$

Three Phase Calculations

The equivalent dielectric circuit in Fig. 11 gives two separate circuits, one Δ (between conductors), and the other Y (between conductors and lead sheath).

E_ϕ = line voltage (variable).

$e_\phi = \frac{E_\phi}{\sqrt{3}}$ = voltage to lead sheath.

$W_{3\phi}$ = total three phase loss (dielectric) per foot

I_ϕ = current per conductor per foot

$\cos \theta_\phi$ = three phase power factor

$W_{3\phi}$ = 3 ($W_3' + W_1'$) where;

W_3' = W_3 read from curves at voltage E_ϕ and,

W_1' = W_1 read from curves at voltage e_ϕ

$\dot{I}_\phi = \dot{I}_3' + \dot{I}_1'$ where;

$\dot{I}_3' = \dot{I}_3 \sqrt{3}$ at voltage E_ϕ and,

$\dot{I}_1' = \dot{I}_1$ at voltage e_ϕ

$$\cos \theta_\phi = \frac{W_{3\phi}}{\sqrt{3} E_\phi I_\phi}$$

also;

$$c_\phi = \frac{I_\phi \sin_\phi}{2 \pi f E_\phi} = \text{capacity, farads per conductor per foot.}$$

Digitized by Google

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 27, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

PRESENT PRACTISE IN THE DESIGN AND MANUFACTURE OF HIGH-TENSION INSULATORS

BY A. O. AUSTIN

ABSTRACT OF PAPER

As considerable time or a severe condition is necessary to show up serious insulator defects, the favorable line conditions on the earlier lines permitted the use of inferior material and designs. The apparently satisfactory operation of inferior insulators together with the large production necessary did much to retard improvement in the insulators, for improvement was practically impossible unless same could be accomplished without materially increasing the cost.

The desire to increase production and improve the material necessitated radical changes in the manufacture and equipment, so that the well equipped plant today is far different from the ordinary pottery which it resembled a few years ago.

The rapid development in the transmission field has materially changed conditions, and rendered much apparatus obsolete, the early insulator being no exception.

As causes of losses have become evident, means have been found to eliminate the serious effects of same. The recognition of the increased value of reliability together with the study of operating conditions has materially changed the insulator situation, so that the material going to the scrap pile today is more suitable for line work than the best product a few years ago. The loss from porosity has been reduced to a negligible quantity by improved firing methods and a closer selection.

To prevent the serious cracking loss noticeable on old insulators, has been the most difficult problem. To prevent trouble on old lines, it may be necessary to give the insulators a temperature, as well as an electrical test.

Trouble from this source on modern insulators is prevented by careful attention to the temperature gradient, increased mechanical strength to resist internal stresses, and a lowering of the internal stresses by means of an elastic joint.

The performance of the modern insulator is very gratifying, and its performance must not be judged by insulators which are really obsolete.

THERE IS often an impression that it is possible to eliminate all insulator troubles by the use of some new design, test or manufacturing method. In order to eliminate trouble, however, it is absolutely necessary that all depreciation be eliminated. The very nature of the dielectric, the large number, necessitating low cost, and the many hazards to which the insu-

Manuscript of this paper was received April 28, 1917.

Digitized by Google

lators are subjected in operation gives us no right to expect that we can hope to equip a line with insulators which have absolutely no depreciation.

Although the depreciation for some one particular cause may be made negligible in the insulator, it is highly important that this desirable result is not obtained at the expense of a greater hazard in some other direction. The best line practise will be that which reduces the principal hazards as far as possible, but takes into account the hazards produced by depreciation, so that a system may be planned and operated accordingly.

From the operating standpoint the insulator problem is one of maintenance, for the state of the art is such that the hazards can be reduced to a negligible quantity where the fundamental factors governing reliability are given due consideration and the line is maintained in a good state of repair.

The length of time required to show up the effects of depreciation and the rapid development of the art together with the low cost of the insulator is largely responsible for the greatest losses.

Material improvements have been made in the design and manufacture so that the performance of the modern insulator cannot be judged by the performance of insulators made even a few years ago.

The production of a satisfactory insulator is no small problem, if the cost is to be comparatively low. Designing necessitates a very thorough knowledge of manufacturing conditions or their possibilities, for it must be remembered that an insulator part usually goes through from 20 to 30 operations and passes through the hands of over 20 operators. To produce the best results, it has been necessary to eliminate heavy labor wherever possible, so improved machinery has been adopted and the modern insulator plant has departed very much in appearance from the pottery and the methods which it followed only a few years ago.

Fig. 1 shows one of the mold conveyors where the ware is cured before taking it out of the molds. Equipment of this kind saves much of the heavy labor, permits of easy inspection and tends to produce uniformity in the insulator and at the same time results in a considerable saving both as to labor and losses in manufacture.

Similar work has been carried out wherever possible in the manufacture, Fig. 2 showing the ware as it is ready for drying. With equipment of this kind, five or six hundred insulators are

Digitized by Google

subjected to practically uniform drying conditions on all sides and at the same time cracking and the handling cost is cut to a small fraction of what it was formerly.

The inspection of ware is very rigid at all stages in the manufacture and a large portion of the ware rejected today is as good, if not better, than the first quality material of several years ago.

It was only a few years ago, that it was difficult to obtain a test of 40 or 50 kv. on a single part without having losses of from two to forty per cent. The state of the art is such at this time that it is possible to test single parts at much higher voltages than large four-part insulators of a few years ago.

Fig. 3 shows some large insulator parts on test under test conditions equivalent to 140 kv. The average loss even under severe conditions of this kind is seldom over one per cent. This has only been possible by careful systematic work. Many of the older lines are equipped with three- or four-part insulators which would have had an assembly loss of 40 or 50 per cent, if they had been given the above test which can be easily carried by a single part today.

In Fig. 4 is shown one of the assembly cars used for suspension insulators. A car of this kind handles 700 insulators and permits of their being cured under the best possible conditions and with a minimum amount of handling. The increased cost, owing to a very much higher standard, has necessitated improved handling methods at every point in order to keep down the cost which would otherwise be considered prohibitive.

Much has been written about the principal electrical characteristics of the insulator, so the discussion of design and manufacture will be largely confined to the two most important elements producing depreciation, cracking and absorption.

Cracking

The cracking of insulators is by far the most serious cause of depreciation on most lines, and has been an important factor in the design of pin-type insulators for some years. In order that the method adopted to reduce this loss may be better understood, it is necessary to consider conditions as found on the line.

For the past seven or eight years, much cracking has been noticeable on pin-type insulators, some lines being entirely reinsulated while on others, it was necessary to locate the faulty material by visual inspection or by ringing out with a stick. To avoid this loss, pin-type insulators were replaced by suspension type in at least one instance.

Digitized by Google

The more recent cracking of suspension insulators has attracted far more attention than a similar loss in the pin type. This is largely due to the fact that they could be easily located on the line and to the higher standard of operation on most of the lines where they were used.

A curve which is characteristic of the depreciation for many insulators is shown by *A* Fig. 5. It will be noted that this curve rises rather rapidly for a short time due to absorption and then rises very slowly for five or six years operation when it jumps very rapidly due to cracking.

In order to see the effects of this depreciation, it is necessary to study the effect upon operation.

Curve *B* shows the operating hazard or probable interruptions for the depreciation shown in curve *A*. It is assumed that a four-part insulator will fail when three parts become bad. Curve B, rises very rapidly after six or seven years as the hazard increases in direct proportion as the cube of the depreciation. This curve shows why cracking is often very serious before its effect is noticeable on the operation.

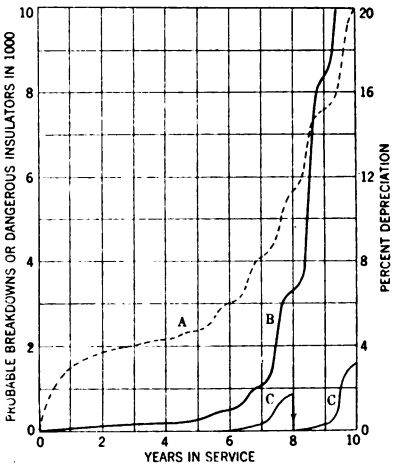


FIG. 5

Curve *C* shows the operating hazard where all defective material is removed every four years. While the removal of faulty material greatly reduces the hazard, it is seen that the cracking during the tenth year would cause 14 probable breakdowns in a lot of 10,000, although there might have been only one or two the year before.

The insulators which crack are apparently affected in no way up to the instant of cracking, hence, it is impossible to anticipate their failure by any practical electrical test. Porous material on the other hand, can be detected and removed before it becomes valueless.

Owing to the small margin of safety and the nature of dielectrics used for insulators, it is not reasonable to assume that depreciation can be entirely eliminated. A low depreciation is

Digitized by Google

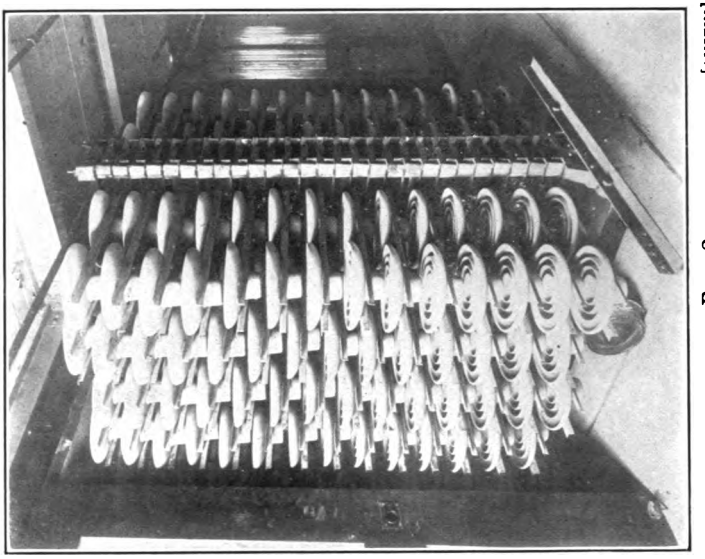


FIG. 2 [AUSTIN]

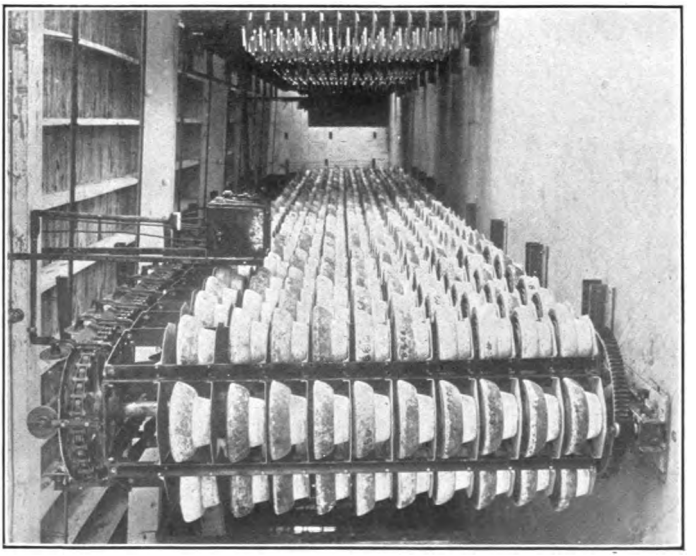


FIG. 1

Digitized by Google

Digitized by Google

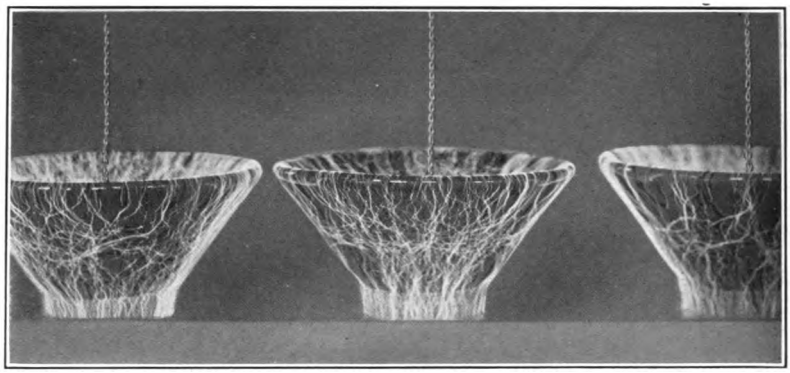


FIG. 3

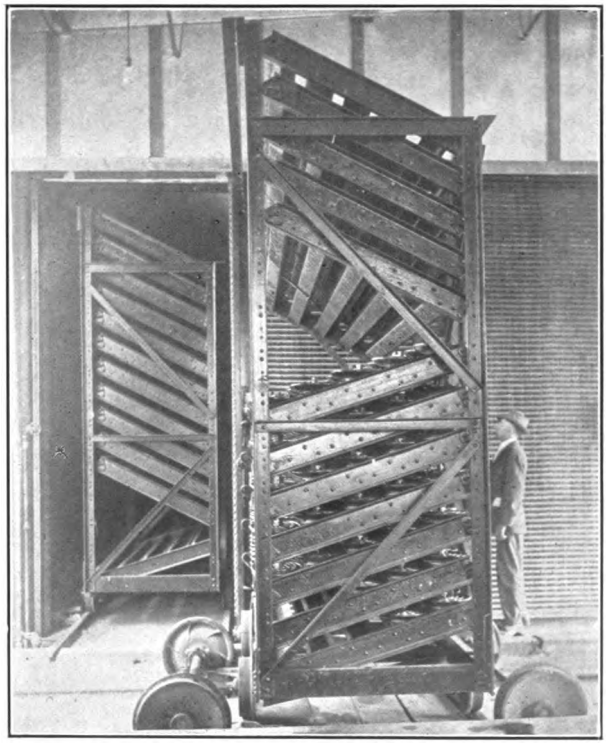


FIG. 4 [AUSTIN]

Digitized by Google

Digitized by Google

well worth while, however, as it permits the use of insulators of fewer parts with their smaller maintenance.

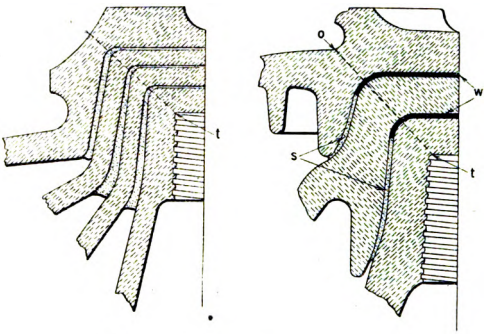
Examination of many insulators which have cracked on the line indicates the following:

1. That the largest and apparently the strongest insulators crack soonest.

2. That the size, shape and number of the cemented joints effect the cracking.

Old insulators when heated up slowly will often crack before they reach 150 deg. fahr. The parts which fail are the tops or shells outside of large cement spaces.

When old insulators are heated up and then have their tops sprayed with water similar to a thunder storm, a very much



A FIG. 6 B

larger per cent of cracking takes place. This, however, is usually confined to the head of the insulator.

Insulators like that shown in *A*, Fig. 6 may have a very high loss on a single heating and cooling cycle. Designs similar to *B*, however, stand very much more severe treatment without loss.

There is a very noticeable cracking on the heads of insulators similar to *A* after five or six years, weathering. If insulators are subject to the elements, it appears to make no difference whether they are in service or not.

When old insulators which are heated and sprayed with water, crack, the failure is announced by a sharp report, indicating a force of considerable magnitude. Insulators which have stood a heating and cooling cycle of higher range are little effected by a number of cycles of lower range.

These together with the absence of any electrical indication

Digitized by Google

of weakness go to show that the cracking is due to a high stress rather than fatigue.

It has been pointed out that the stress may increase due to a slight expansion of the cement with time. This stress in itself may not be serious, but combined with others may cause failure. The cement adheres more firmly to the porcelain with time so that any adjustment by slipping may become less. It is also possible that the modulus of elasticity of the cement may increase with time. The accumulation of dirt may cause a greater leakage of current, heating up the inner parts, or the insulators may get hotter in the sun. The poorer heat conductivity of the cement is still another factor.

While it is true that porcelain or glass will fail at a lower ultimate if the stress is applied for a long time the stress required to cause failure is very high.

Under operating conditions an insulator may reach 150 or 160 deg. fahr. in the sun. Under these conditions insulator *A*, Fig. 6 will have a temperature gradient along the line *O*—*t* like that shown in *A* Fig. 7. If rain falls on the upper surface, the temperature may be represented by *A'* after a few minutes. Under similar conditions, the temperature gradient for insulator *B* is shown by *B* and *B'*.

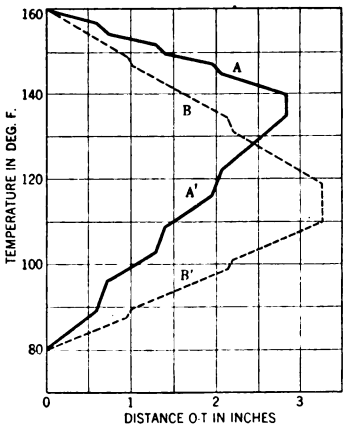


FIG. 7

It will be noted that the inner parts of the older type of insulator get very much hotter than those in *B*. It is further noticeable that the radiation of heat from the inner parts is less in *A* than in *B*, so that when the heads of the insulators are cooled to the same temperature, the temperature gradient will be much steeper in *A* than in *B*, so that the stress set up between the porcelain parts regardless of the cement will be very much higher in the older type insulator.

The cement has a higher linear coefficient of expansion than the porcelain and will produce a very high stress if of large cross section. The practise then of reducing the size and area of the cement joint may reduce the stress set up by the cement to easily less than half that for the older insulators.

Digitized by Google

The advantage in fewer cement joints and small heads on the insulators has been carried out extensively in the modern two-piece insulators for voltages up to 50 kv.

Much effort has been expended to incorporate the following in the modern pin-type insulator:

1. A few strong parts.
2. Small heads with corresponding cement sections and areas.
3. Minimum amount of nesting permissible with mechanical reliability.
4. Elasticity in the joint.

A few strong parts keep down the renewals when the line is cleared up for the loss will increase nearly as the product of the per cent loss on a part and the number of parts. This is important and will show up sooner or later on the line.

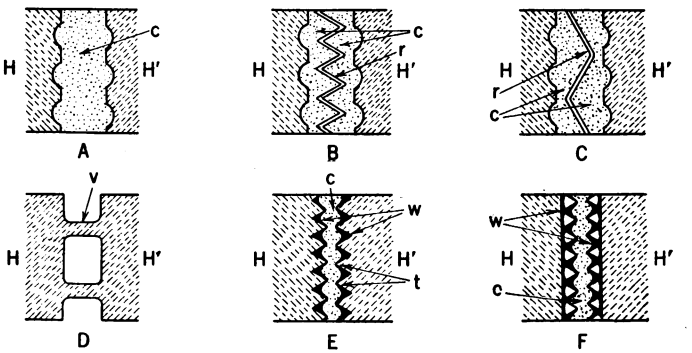


FIG. 8

The axial pressure tending to force the top out of the head in *A* is entirely eliminated in *B* by coating the ends of the shells by a wax *w*, or the use of a cushion.

The grip surfaces *S* are sanded and as the grip is of very high efficiency, a minimum surface may be used for mechanical reliability. Since this surface grips in all directions equally well, there is a tendency for the insulator to hold together even when badly damaged mechanically. This is particularly important for an insulator where the parts are not deeply nested.

ELASTICITY OF THE CEMENT JOINT

In Fig. 8 are shown several types of joints which are of particular interest in considering cracking. In *A* is shown the ordinary cement joint with scored surfaces held together by cement *C*.

Digitized by Google

In *B* and *C* is shown an elastic or yielding insert *r* placed in the joint. In *B* the possible movement would be greatest across the joint and in *C* lengthwise of the joint. This then is one method for regulating relative movement in the joint either axially or radially.

Although a joint as shown in *B* or *C* will relieve any internal stress, it is not good for handling heavy loads and the danger of the insulator falling apart and dropping the line is increased so it is not used except in special cases.

The insulator joint will be satisfactory in so far as it fulfills the following:

1. Minimum area for a given grip.
2. Absence of slipping.
3. Elastic yield or ability to distribute a heavy load.

The coated-sanded surface fulfills all these requirements to a marked degree, as will be seen by a consideration of *D*, *E* and *F*.

By reference to *D*, it is seen that any force between *H* and *H'* must be exerted through the small struts *V*. If the force is one of compression, the stress in the main members *H* and *H'* will be very small compared to that in the struts *V*, being in inverse proportion to their cross sectional areas. If there were a number of these struts, their area could be so proportioned that they would compress or crush and limit the stress at any point in *H* or *H'*. This method of connecting the different members would prevent looseness of the parts and would give a good stress distribution in practically any direction for the strain would occur in the small struts *V*.

In *E* is shown a practical method of accomplishing the stress distributing feature of *D*. The main insulating members *H* and *H'* are provided with ridges or projections *t*. If the joint is entirely filled with cement, conditions will be no better than in *A* so the surfaces are coated with paraffine or other material *W* which accumulates in the bottom of the grooves leaving the points only very thinly covered. The bearing of the cement is then confined to the tops of the projecting ridges or points which act in the same way as the struts in *D*. Under these conditions, it is seen that the stress per unit area at the points *t* and the adjacent cement will be many times that in *H* or *H'* so that the joint will give and relieve the main parts from heavy strain, produced by unequal expansion between the parts or cement.

A low coefficient of elasticity can be obtained in *E* by controlling the size and depth of the ridges or points and the coating

Digitized by Google

used to regulate the effective area of contact between them and the cement.

While *E* fulfills the general requirements, the grooves tend to concentrate the stress and the failure of a point may start a crack in the body of the piece. It also has the further objection in having a small give in the direction of the joint.

The sanded surface *F* provides the projections similar to *E*, but the space filled by the wax is much greater. This joint not only limits the stress much better in all directions but is easily made and is free from the objectionable feature of scoring.

Ordinary surfaces cannot be covered with wax or paint to relieve the stress unless the load is very light, as the bearing may be concentrated in one or two points, causing a low ultimate or cracking.

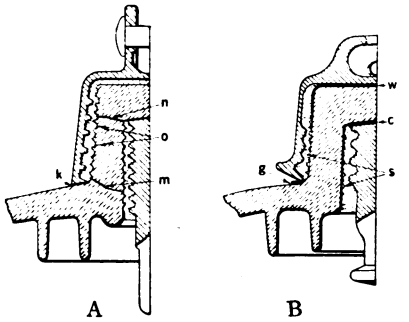


FIG. 9

By proper control of the sanding, it is possible to eliminate hard spots or undue concentration of stress in many insulators, giving a higher ultimate in the suspension insulators without the danger of cracking.

CRACKING OF SUSPENSION INSULATORS

The cracking of insulators was covered to a large extent in a paper on Insulator Depreciation, December 1914. This discussion outlined very briefly, the causes of cracking and methods of reducing same. In order to insure the mechanical reliability of the insulator, it is advisable that the cap bear on the flange to prevent the escape of cement while setting. This contact area is shown at *K* in Fig. 9. Cutting the cap with a slot just above this point or the putting in of new cement at *K* showed that the insulator could be heated much higher without starting

Digitized by Google

a crack at *m*. This proved that the stress was due to the elongation of the cap and expansion of the cement.

A higher assembly temperature would tend to eliminate cracks *o*, but would do little good at *m*, if the cement at *k* expanded, so the first improvement was to reduce the bearing area at *K* using a cap like that shown in insulator *B*. Insulators cemented in this way stood many cycles between freezing and boiling without showing damage. In practise, however, it was found that cement which filled in below the cap would not loosen and drop out; furthermore, the cap came in contact not on a 45-degree line as intended, but out on the flange in some cases.

To insure positive relief at point *K*, rubber gaskets were first used at the lower edge of the caps, or they were dipped or painted with wax or asphaltum but various types of paper felt gaskets were finally used. Some of these gaskets were left in and some removed, the present practise being to remove the gasket.

The present practise is shown in *B*, Fig. 9. The head of the insulator is covered with a wax or paraffine *w*, a disk *C* is used at the end of the pin and a gasket at *G*, the latter being removed after the cement has hardened.

All grip surfaces are sanded and a moderate assembly temperature used so that dangerous shearing stresses will not be set up in cold weather. With machined or highly refined caps, it is possible to go to very high assembly temperatures. Without these refinements, however, a high assembly temperature is not advisable.

The use of the elastic sanded surface for limiting the stress together with the assembly shown in *B*, so materially improves conditions that the danger of cracking is certainly very much reduced or practically eliminated at least for a very much longer period.

The higher the mechanical ultimate in the insulator, the more difficult it becomes to design or manufacture so as to keep down the internal stress.

Although the sanded surface permits of the design of very much higher ultimates in the cemented type of strain insulators, it is probably best practise for very heavy loads to use insulators which place all the stress on a wood or fiber core similar to those shown in Fig. 10. Insulators of this type are in operation on the highest voltages and on loads up to 35,000 pounds

Digitized by Google

and can be designed for practically any mechanical ultimate without making the conditions any more severe as to the dielectric.

While a close selection is made as to vitrification, it might be well to note that the heating of the insulator will melt the paraffine or wax on the head of the insulator which will impregnate the cement and porcelain, should it be porous.

Further refinements will be made from time to time, but it would seem that the present standard is such that they will have to be made without materially increasing the cost.

The coated sanded surface still offers refinements at minimum cost and it would seem that improvements in the near future will be along this line, particularly if it seems necessary to provide elasticity in the pin for better stress distribution.

Absorption

The loss by absorption or porosity may vary widely on different systems and for insulators manufactured at different times. Since most of the porous material can be detected by the trained eye, the question naturally arises as to the conditions which permitted its installation. It is even more important to know how this can be guarded against in the future.

The routine tests made on insulators up until 1903 were made with dry electrodes and were often made on the nested parts at very low voltages as compared to present practise. Under these conditions very porous material would pass tests successfully and it is certain that some lots of insulators included fifty per cent of material which would be classed as porous with present standards.

Although tests were made from 1903 on, with water inside and outside the insulator parts, most of the insulator parts were tested inside of two minutes after applying the water and then packed and shipped to be assembled in the field later and installed without further test. Under these conditions some of the poorest material was eliminated but large percentages of insulator parts were frequently installed which furnished but little insulation by the time they were in place.

Much material was installed as late as 1905 which showed a fifty per cent loss on second test after soaking 24 hours. Most of this material was used on wood construction and on the Pacific coast where conditions were favorable; otherwise, very serious trouble would have resulted.

Digitized by Google

By the end of 1906 tests had not only been raised, but insulators were assembled in the factory and were beginning to be given a final test. This did much in some instances to eliminate porous material, but as assembled tests were seldom over 70 per cent of the flashover of the insulator, many pieces of porous material could pass the assembled test which would have been detected on a higher test voltage.

Many different designs were made in the next few years and in some instances desirable forming properties were developed in the clay to facilitate manufacture. These desirable properties were developed at the expense of vitrification with the result that some large lines were equipped with material which, although standing a high unassembled part test, was very weak dielectrically after installation on the line.

While there was a general improvement in the vitrification up to 1910, operating conditions were becoming more severe, which had the tendency to offset this improvement.

Thicker material was used on parts to give greater dielectric strength, and as it takes a considerably longer time for absorption to take place with increasing thickness, the greater weeding out of the higher test voltages was largely offset.

Much of the ware put out in 1909 and 1910 showed a loss of less than two per cent by absorption when examined several years later, although material was considered as vitrified over approximately a four-cone range, 80 deg. cent.

To obtain properly vitrified material which will not fail by absorption it is necessary,

1. That the body composition be such that it will vitrify to the extent that the pores will be sealed against absorption.

2. That all material be fired to the proper temperature and time for the body composition used.

To obtain the first condition many checks are necessary in order that uniformity be maintained. The general composition may be entirely satisfactory and spoiled in the manipulation due to a streak of off mixture from settling. This streak or a path left by the burning out of lint may absorb water and render the insulator worthless later. Material improvements have been made in the compounding and working of the clay in the last few years, so that some of the worst hazards cause but little concern at the present time. Better equipment had to be designed and placed in operation to eliminate the most serious cases of trouble, while additional checks were used to cut down others.

Digitized by Google

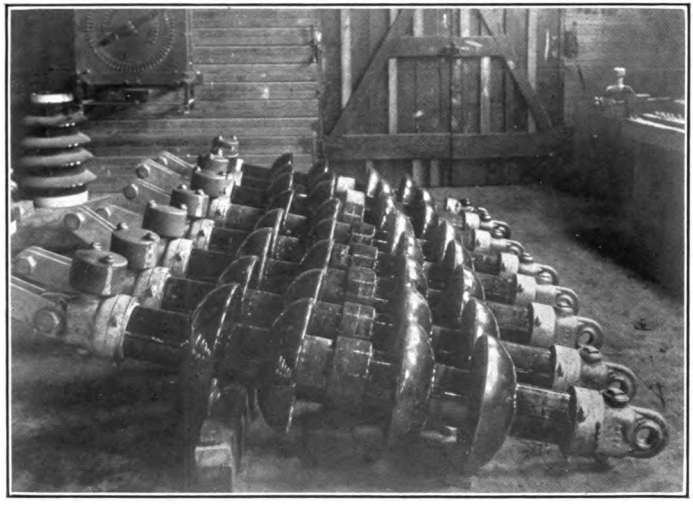


FIG. 10

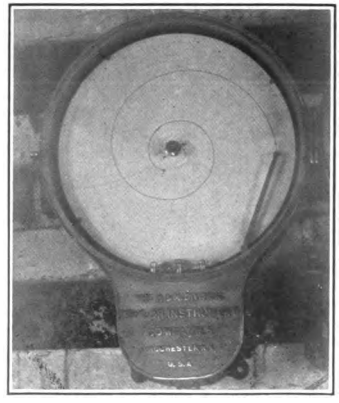


FIG. 11 [AUSTIN]

Digitized by Google

Digitized by Google

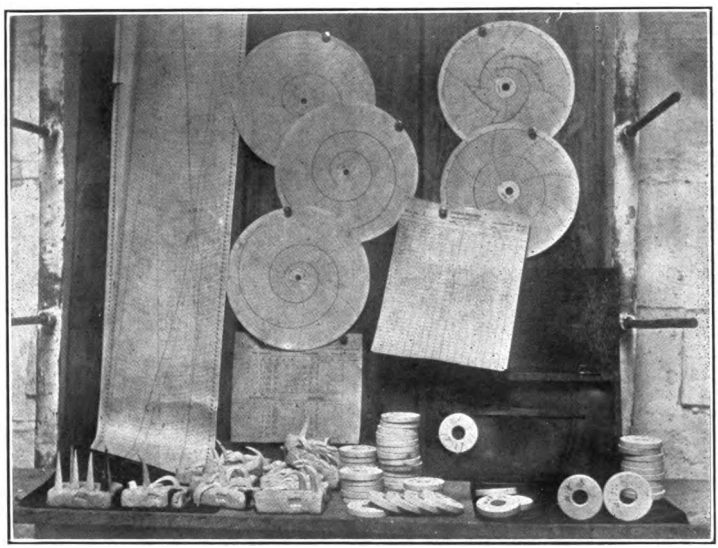


FIG. 12 [AUSTIN]

Digitized by Google

Digitized by Google

Uniform viscosity in the slip and time of pumping the filter presses were prime factors in eliminating streaks of off mixture.

Firing or Burning of the Ware

The important factors in obtaining satisfactorily vitrified ware are:

a. A means of determining the firing history of each individual piece.

Where a glaze is used for the insulator which has a wide range of color for a slight difference in temperature, the selection as to temperature or firing history is fairly easy for the trained eye. Glazes such as slate, white, yellow, caramel or Albany slip glazes where the calcium content is too high, change little over a wide firing range and make selection as to firing difficult or practically impossible.

b. A body composition that is satisfactorily vitrified over as wide a temperature range as possible.

In guarding against porous material, the use of a body composition of such range of vitrification that proper selection can be safely and economically made inside this range is an important factor.

c. Close control of the firing of the ware.

Some body compositions have such a very short range of vitrification that a selection extending not over a range of two cones may include both over and under fired material.

Only a few years ago, the use of a glaze which had too uniform color over a wide temperature range together with a body composition of short range of vitrification, while apparently very satisfactory at the time was largely responsible for a considerable number of insulators becoming bad through absorption.

It is always possible to obtain good ware by selection where factors *a* and *b* are favorable although factor *c* is anything but good. Unless the firing control is good, it is not possible to make a close selection of ware without a heavy rejection which would materially affect the cost.

Much work was required to improve firing conditions so that the selection could be reduced from a four-cone range, 80 deg. cent., to practically a two-cone range, 40 deg. cent. Kilns had to be reconstructed so as to have less difference between the hottest and coolest places, and a method of feeding the fuel used which was largely independent of the personal element.

Recording mercury thermometers were used to indicate tem-

Digitized by Google

peratures up to 1000 deg. fahr. These thermometers do not control the firing, but serve as a check of the method and give data for correction of same.

Reference to the chart in Fig. 11 shows that the rise in temperature is under perfect control, which is very desirable so as to eliminate firing checks in heavy ware. In addition to the use of mercury recording thermometers up to 800 or 1000 deg. fahr., a recording electric pyrometer is used to indicate the rate of temperature change in firing and cooling.

For indicating the finishing temperature, pyrometric cones are used and also disks or rings whose shrinkage can be accurately measured.

Fig. 12 shows a set of records and trials now used for a single firing. Until two years ago, the Seger cones and the experience of the kiln burner were the only guides in firing. Highly skilled firemen, even where gas was used for fuel were unable to produce a satisfactory result for the narrower limits until a system was adopted that was largely independent of the personal factor. Consequently the control was not nearly as good as at present.

The fact that much ware put out some years ago selected over twice the firing range of that at present had an exceedingly small percentage of porous material, would indicate that there is little cause for concern with present material, if factors *a* and *b* are at all favorable and a careful selection made.

The present practise of using much thicker porcelain tends to minimize the danger due to absorption, for it is possible that a drying out action may start before moisture has extended entirely through the part. The time of complete penetration is controlled by many factors, but may be regarded as increasing as some power of the relative thickness when comparing two pieces of the same vitrification.

Unless conditions are favorable, it is seen that resistance tests which require that moisture extend entirely through the piece to detect porosity may require entirely too much time unless made on thin pieces. Before tests could be made on thick pieces, they would be on the line.

It is the general factory practise to depend largely upon dielectric tests made before and after soaking or assembly. These tests indicate the point where even slight absorption takes place and the selection for vitrification is such as to keep away from the danger point.

Digitized by Google

TESTS

While a thorough discussion of tests is beyond the scope of this paper, those in general use deserve some attention.

With the thickness of material used in the present insulator, tests just below flashover are hardly severe enough. If, however, the regulation of the circuit is poor and the voltage is raised so that a violent flashover is produced, a very effective weeding out of poor material is obtained.

The test in Fig. 3 is of this nature, and is undoubtedly the best all around test method in use. A few insulators or a great many can be tested with certainty, which is no small advantage where thousands of insulators have to be tested daily.

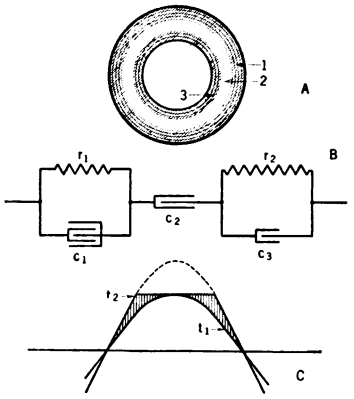


FIG. 13

A brief analysis of conditions in Fig. 13 will show why this test is so efficient in detecting material which is porous.

In *A*, the section of an insulator is shown which has absorbed moisture so that there are two wet zones 1 and 3 adjacent to the cement surfaces with a dry zone 2 between.

The porous zones may be regarded as condensers and resistances in multiple, which are in series with a condenser represented by the dry zone. The arrangement is shown diagramatically in *B*.

The impressed voltage under different conditions is shown in *C*. t is the voltage on the series of zones at 60 cycles, the maximum voltage being just under flashover.

If the voltage is raised until the insulator flashes the effective voltage on the series will be represented by t_2.

The resistances r_1 and r_2 may be very high so that the porous zones will carry an appreciable portion of the total voltage on the piece. Owing to the phase displacement of the voltage over the different zones, the dry zone will be subjected to a large percentage of the total voltage.

It is evident that where t_2 represents the impressed voltage, conditions will be much more severe on the dry zone for the leakage over the resistance will be greater. That this is necessarily true is seen, for if the frequency was zero, zones 1 and 3

Digitized by Google

would, of course, carry no voltage, the entire voltage being concentrated on zone 2.

This shows that the lower the frequency or the flatter the wave, the greater the stress on the dry zone. In t_2 the rise in voltage is more rapid than in t_1 which tends to place a higher stress on zones 1 and 3 than in t_1, but owing to the greater length of time the maximum voltage is applied the dry zone will also receive more stress than in t_1.

It is evident that increasing the frequency to 200,000 cycles will give little time for the leakage of charging current through r_1 and r_2, so that a porous piece will act as though it were a perfectly good piece and the chance of elimination on test by failure of the dry zone is very much less.

In t_2 the insulator flashes and is subject to several surges during each alternation. This affects the concentration of stress on the dry zone C_2, but little, while subjecting the wet zones C_1 and C_3 to their proportion of the voltage, which they would carry if they were dry.

From this, it follows that a test made at normal frequency so that the insulator flashes heavily without picking up a power arc tends to place maximum stress on all zones.

The fact that the conditions of normal frequency as well as high frequency are present at the same time undoubtedly accounts for the effectiveness of this method of test in eliminating material which tends to become faulty under line conditions.

Conclusions

It is hoped that the above brief outline of insulator practise will indicate the possible differences between an old and a modern insulator, for it would appear that much concern is felt over what are chiefly the defects of old insulators.

The insulator is subject to many hazards and as the design is a compromise at best, it is not surprising that certain properties should be developed at the expense of others. It is gratifying, however, to note that the chief troubles have been along lines not looked for.

The rapid development of the art has rendered much transmission apparatus obsolete, and the insulator is by no means an exception. When in addition to this, we take into consideration that little is generally known even at the present time as to the conditions under which the insulator has to operate and the necessary properties in same to withstand these conditions, it

Digitized by Google

is surprising that the insulator has reached its present state of perfection.

It has been a number of years since the operating voltage has been limited by the insulator, and the performance of many lines put in during recent years shows that the modern insulator has more than justified expectations even in the face of higher standards of operation and increasing severity of line conditions due to the growth of the system or mechanics of the line.

The fact that the design is a compromise calls for the most careful thought in the design and manufacture, and the successful line will be constructed with insulators which have been improved along lines which are shown to be necessary by time and experience rather than along radical lines that may incorporate elements which will cause serious trouble in unlooked for quarters after a few years operation.

It is much easier to locate the cause of trouble than it is to effect a cure, for the insulator works on exceedingly narrow margins, and it is difficult to find a means of strengthening the insulator for one set of conditions without materially affecting another.

It is well to note that the above paper deals chiefly with the means which have been employed to eliminate some of the worst defects without sacrificing the properties in other respects proven to be good.

The abnormally low depreciation and successful performance of well insulated lines under the severest conditions show that the modern insulator is very successful compared to the earlier product, and if properly made, the standard is such that further improvements are not warranted if they greatly increase the cost.

For old lines, it is well to consider the increasing hazard with time due to an increasing rate of depreciation. To maintain a given standard of performance, it is then necessary to either split up the system into smaller sections as the line becomes older or to go over the line at decreasing intervals of time to remove the faulty material. It is possible that considerable benefit can be obtained on some systems by putting the old insulators through a temperature cycle, as well as the usual tests, to eliminate faulty material.

The fact that some of the weakest points in the insulators were greatly improved by design or manufacture without materially affecting the cost, did much to insure progress for a considerable

Digitized by Google

period when troubles were only occasionally noticeable. The present situation shows that these improvements give every promise of being not only very valuable, but necessary for a long life and are worth many times the effort required to produce same.

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 28, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

ECONOMICAL COMBINATION OF WATER POWER AND STEAM PLANTS AND A CONVENIENT METHOD OF SOLUTION

BY H. ST. CLAIR PUTNAM

ABSTRACT OF PAPER

A determination of the respective economic limits in steam and water power plant developments., Formulas are derived for determining total annual costs of each type of plant and the most economical combination. Certain general conclusions are reached as follows: Practically all water power plants should be developed beyond minimum power available and hence in combination with a steam plant. The economic limit depends largely on the value of money, fuel, labor, the increasing efficiency of steam turbines and the location of the enterprise.

IN THE development of an industry it is important to carefully consider possible improvements that may be made in methods and efficiency. Of equal importance is the prompt recognition of changes in conditions which affect the industry. During recent years these factors have been especially important in the development of power station practise. The perfecting of the steam turbine, the great increase in the practicable capacity of generating units, the larger boilers used, the use of higher steam pressures and higher superheat, and improvements in automatic stokers, have added thirty or forty per cent to the overall station efficiency within the past ten or fifteen years. Progress also has been made in the design of water turbines. The efficiency of water turbines has been increased from near 80 per cent to over 90 per cent of the potential water power available, and the size of the generating unit has been materially increased.

The improvement in power station efficiency, both in steam and hydraulic practise, has been great, but of greater importance is the change introduced by the change in conditions. Foremost among these changes in conditions is the fact that the modern power plant, whether water power or steam, is a highly efficient manufacturing plant producing electric power for sale in

Manuscript of this paper was received May 19, 1917.

Digitized by Google

large blocks as well as for retail. The recognition of this function of the modern power plant to supply large blocks of power for industrial use has resulted in the development of large highly efficient power stations manufacturing electric power as a business. The industrial use of electric power has greatly increased in recent years, but there are large amounts of such industrial power still independently produced, and much of this can be more economically supplied from central power stations.

Probably the greatest change in conditions, however, has been introduced by the development and perfection of long distance high-voltage transmission lines. Transmission lines are now built of steel with factors of safety equivalent to those used in the construction of bridges and office buildings. This renders them practically immune from mechanical failure. Improved methods of insulation, the increase in voltage, and the development of methods of protection against short circuit and lightning have reduced electrical failures to mere surges, in most cases, so that records show that the interruptions to service resulting from the failure of high-voltage transmission lines are not in excess of those which occur in the ordinary operation of the modern power station. The comparatively unreasonable fear of the reliability of transmitted power is diminishing, and it may be expected to disappear when transmission lines are constructed with adequate factors of safety and when they are properly protected against electrical disturbances, by devices which have been already tried out and proved effective.

The practical development of the transmission line has opened wide fields for the economic development of power. Within reasonable limits, power stations can be constructed where power can be most economically produced. The successful transmission of power over distances of from one hundred to two hundred miles has given great impetus to the development of water powers on a large scale, and only recently, in this country, it has been applied not less effectively to the transmission of power from steam plants located at the coal mines, where cheap or waste coal can be obtained and utilized. The public has become accustomed to the transmission of electrical energy from water powers for long distances, but as yet the possibilities resulting from the transmission of energy from steam power produced directly in the coal fields have not been realized, and the advantages resulting from the combination of such cheap steam power with existing and undeveloped water powers are not fully appreciated.

Digitized by Google

The development of large steam and water power plants, and the improvements made in the transmission of power, have raised new problems as to the most economical method of operation and combination of the several power plants. It is no longer good engineering to regard a power project as self-contained, to be concerned only with its immediate power market, but it must be considered and studied in connection with other power plants, and its design and development should be planned to meet possible future connections with such plants.

This general subject was discussed by the writer in a paper on the "Conservation of Power Resources,"* presented at the

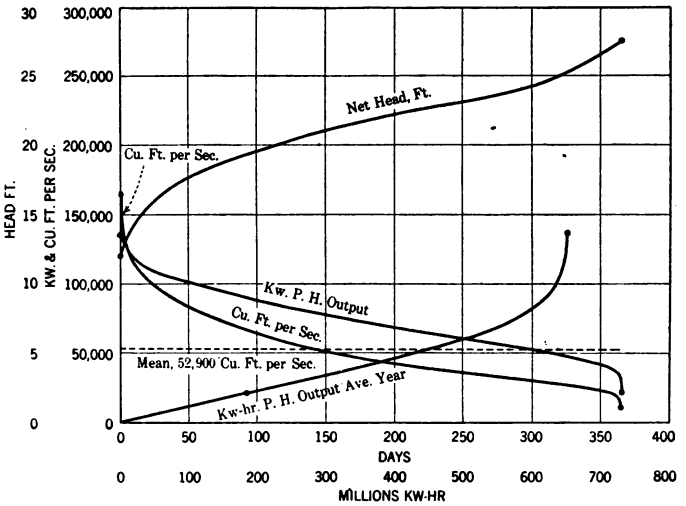


FIG. 1—DURATION CURVE OF FLOW—AVERAGE OF 15 YEARS

first national conference called by President Roosevelt, in 1908, on the Conservation of Natural Resources. In this paper the economic development and combined operation of large water power and steam plants were strongly urged. It is the purpose of these notes to describe a relatively simple method of solving the different problems that arise in combining different power plants with different costs and different operating characteristics, and especially the use of the method proposed to determine the

*"Conservation of Power Resources," by H. St. Clair Putnam. Presented at the Conference on the Conservation of Natural Resources, White House, Washington, D. C., May 13-15, 1908; reprinted in TRANSACTIONS A. I. E. E., Vol. XXVII, p. 1398.

Digitized by Google

feasibility of water power developments, and the magnitude to which such developments should be carried.

Primarily, the proposed method of solution is based upon careful estimates of the cost of construction of such power plants as may be required initially, and a second estimate of the same plants extended to greater capacity, preferably to not less than double the size of the initial plant. Careful estimates are then made of the annual capital costs of each and the operating costs at two or more load factors. The method is equally applicable to water power plants and to steam plants, and naturally can

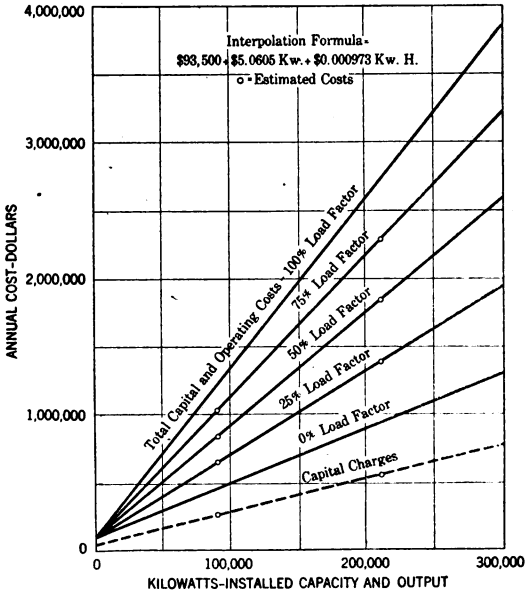


FIG. 2—STEAM POWER STATION—ANNUAL COSTS

be extended to transmission lines and substations and also to existing power plants and systems. As illustrating the general method of solution proposed, some estimates of cost which were prepared for a rather special case where special conditions existed are given. The purpose of these estimates was to determine the feasibility of a low-head water power development represented by the data plotted in Fig. 1, and also the economic capacity for which it should be designed. For the purpose of determining possible economic combinations, the results of the water power development were combined with the results which

Digitized by Google

could be obtained from a well located steam plant of modern design. These estimates are used only to illustrate the method employed, and while they are approximately correct, their accuracy is not essential to the purpose of this paper.

ESTIMATED COSTS
WATER POWER PLANT

Installed Capacity....	100,000 kw.		200,000 kw.	
Dams, dykes, locks, tail race and power plant, complete, including overhead costs.....	$12,200,000		$19,266,000	
Annual Cost:	*25% L.F.*	*75% L.F.*	*25% L.F.*	*75% L.F.*
Interest, depreciation and taxes	$522,350	$522,350	$872,500	$872,500
Operation and maintenance.....	96,080	157,180	161,890	284,090
	$618,430	$679,530	$1,034,390	$1,156,590

Formula—First cost: $5,134,000 + $70.66 per kw.

Capital cost..$172,250 + 3.5010 per kw.
*Operating cost 30,270 + 0.3526 per kw. + 0.0001395 per kw-hr.

Total annual cost $202,520 + 3.8536 per kw. + 0.0001395 per kw-hr.

*The formula for operating cost is derived from the estimates of operation and maintenance, as follows:

100,000 *Kilowatt Plant.*

Operating cost	75% L.F.	$157,180
" "	25% L.F.	96,080
Increment	50% L.F.	$61,100 = 0.611 per kw.

Increment cost 25% L.F. = $0.3055 per kw. = $0.0001395 per kw.-hr.

Operating cost, 25% L.F. (above)	$96,080
100,000 kw. @ $0.3055	30,550
Plant constant, 100,000 kw	$65,530

200,000 *Kilowatt Plant.*

Operating cost 25% L.F.	$161,890
200,000 kw. @ $0.3055 (above)	61,100
Plant constant, 200,000 kw	$100,790
Plant constant, 100,000 kw. (above)	65,530
Increment..100,000 kw	$35,260

Increment cost $0.3526 per kw.

Constant.

Plant constant 100,000 kw. (above)	$65,530
100,000 kw. @ $0.3526	35,260
Constant	$30,270

Formula—$30,270 + $0.3526 kw. + $0.0001395 kw-hr.

The same general method is employed to derive the other interpolation formula, used in this paper, from the estimated costs.

Digitized by Google

The corresponding costs for a steam plant constructed in accordance with the best modern practise and located immediately at the coal mines where suitable coal can be obtained at an average price of $1.00 per ton, are as follows:

	Steam Power Plant			
Installed Capacity	90,000 kw.		210,000 kw.	
Ground, building equipment, coal tracks, and storage and condensing water facilities....	$5,062,350		$10,643,230	
Annual Cost:	*25% L.F.*	*75% L.F.*	*25% L.F.*	*75% L.F.*
Interest (3%), depreciation and taxes....	$265,430	$265,430	$566,640	$566,640
Operation and maintenance.....	385,293	768,850	827,058	1,722,023
Total annual cost	$650,723	$1,034,280	$1,393,698	$2,288,663

First cost—formula: $876,720 + $46.507 per kw.

Capital cost..... $39,530 + $2.5100 per kw. +
Operating cost... 53,970 + 1.5505 per kw. + 0.000973 kw-hr.

Total annual cost.. $93,500 + $4.0605 per kw. + 0.000973 kw-hr.

The estimated annual costs, as given in this estimate, are plotted in Fig. 2, which is a graphic representation of the method used in obtaining the above interpolation formula.

	Transmission Lines	
Installed capacity.....	150,000 kw.	300,000 kw.
Steel tower line and right-of-way.....	$1,484,700	$2,839,400
Annual Cost:		
Interest, depreciation and taxes.....	$62,496	$120,492
Operation and maintenance.....	21,770	36,040
Total.....	$84,266	$156,532

Formulas—First cost..... $149,950 + $8.965 per kw.

Capital cost..... 4,450 + 0.387 " "
Operating cost..... 7,520 + 0.095 " "

Total Annual Cost..... $11,970 + $0.482 " "

Digitized by Google

SUBSTATION—DISTRIBUTION

Installed capacity	90,000 kw.	240,000 kw.
Substation building, transformers, switching gear, lightning arresters, etc.	$600,000	$1,500,000
Capital cost	$33,000	$82,500
Operating cost	11,000	22,500
Total Annual Cost	$44,000	$105,000

Formula—First cost $60,000 + $ 6.00 per kw.

Capital cost	$ 3,300	+ $0.330 per kw.
Operating cost	4,100	+ 0.077 per kw.
Total Annual Cost	$7,400	+ $0.407 kw.

The above estimates are based upon interest at 3 per cent and coal $1.00 per ton. In the table below, transmission losses are taken at 6 per cent and the load factor at 100 per cent. The market for power is assumed to be at the water power end of the line. The resulting costs expressed in terms of power delivered to the distribution system, in terms of the derived formulas, are as follows:

RESULTING FORMULAS—100 PER CENT LOAD FACTOR
6 PER CENT LOSSES ADDED.

Construction Costs.

A.	Water Power Plant	$5,134,000	+ $70.660	per kw.
(1)	Steam plant	$ 876,720	+ 49.297	"
(2)	Transmission line	149,950	+ 9.503	"
(3)	Substation at W. P. end	60,000	+ 6.000	"
B.	Total for Steam Plant	$1,086,670	+ $64.800	"

Interest (3%) and Depreciation.

C.	Water Power Plant	$ 172,250	+ $3.501	"
(1)	Basis 8% interest, etc.	428,950	+ 7.034	"
(2)	Steam plant	$ 39,530	+ $2.661	"
(3)	Transmission line	4,450	+ 0.410	"
(4)	Substation	3,300	+ 0.330	"
D.	Total Steam Plant	$ 47,280	+ $3.401	"
(1)	Basis 9% interest, etc.	$ 112,480	+ $7.289	"

Digitized by Google

Operation and Maintenance.

E.	Water Power Plant	$ 30,270	+	$1.5746	"
(1)	Steam plant	$ 53,970	+	$10.6751	"
(2)	Transmission line	7,520	+	0.1007	"
(3)	Substation	4,100	+	0.0770	"
F.	Total Steam Plant, $1.00 coal	$65,590	+	$10.8528	"
(2)	" " " 3.00 "	88,910	+	26.6368	"

The Problems to be Solved

1. *When the Development of a Water Power will Secure Better Results than the Construction of a Steam Plant.* One of the first questions to be determined in the development of a water power is whether or not it will pay, and if so, whether it is the cheapest and best method of producing the power required. In the case used as an illustration, the water power is compared with a steam plant of modern design, located at the coal mines, thus reducing the cost of fuel to a minimum. The comparison, therefore, is most severe. After the above described cost formulas are developed, the problem is quickly solved. On the basis that the power is to be delivered to a local distribution system at approximately 13,000 volts and 100 per cent load factor, the formulas derived above become as follows:

Total annual cost, water power,	$202,520 + $5.076 per kw. $(C+E)$
Total annual cost, steam power,	112,870 + 14.253 per kw. $(D+F)$

Then the point of equality of cost will be found as follows:

$$\$202{,}520 + \$5.076 \text{ per kw.} = \$112{,}870 + \$14.253 \text{ per kw.}$$

$$\text{kw.} = \frac{89{,}650}{9.177} = 9{,}769$$

That is, if the power required is in excess of 9,769 kw., it is better to develop the water power than to build the steam plant.

2. *When it is Better to Construct the Water Power Than to Extend an Existing Steam Plant.* If the steam plant is already built, and additional power is required, then the question arises whether it is better to extend the steam plant or to construct the water power.

This question is answered as follows:

$$\$202{,}520 + \$5.076 \text{ per kw.} = \$14.253 \text{ per kw. } (C+E = \text{inc.}D + F)$$

$$\text{kw.} = \frac{202{,}520}{9.177} = 22{,}068$$

Digitized by Google

That is, if the increased power desired is in excess of 22,068 kw., it is better to construct the water power plant than to extend the steam plant. As stations of large capacity are here considered, and the steam station is assumed to be equipped with 30,000-kw. or 35,000-kw. steam turbines, it is evident that it is better to construct the water power than to install an additional unit in the steam station.

As has been stated, the estimates used in this memorandum are based upon the development of a water power with a low head, but with a large volume of water. The characteristic discharge curve for such a stream, together with the potential power that can be developed and the variations in head with different flows, are shown in Fig. 1. It will be noted that, with the exception of but two or three days in the period of fifteen years, the power during low-water periods does not drop below 30,000 kw. It is evident from the above deductions, therefore, that the water power should be developed under the conditions assumed, rather than that a steam plant and transmission system should be constructed, or the steam station extended.

Water Power with Steam Auxiliary

It has been found profitable to develop water powers much beyond the minimum flow of the stream when a market for the power is available. If there is no market immediately at hand, in many cases new industries grow up and absorb the power after such developments are made. Under such circumstances, as the demand for power in any industrial community constantly increases and the power must be supplied, it often becomes a serious problem to determine how best to obtain additional power when the power in the original development is absorbed.

It is of importance, therefore, to determine in advance the best water power development to make, and to determine as nearly as possible, the manner in which increased demands for power are to be met. There has been a tendency quite general among bankers and investors to regard a water power as limited by the minimum flow, and to look with suspicion upon the proposition to include an auxiliary steam plant as a necessary part of a water power development. As a matter of fact, practically all water powers have auxiliary steam plants in connection with them, but, unfortunately, these auxiliary plants are often uneconomically furnished by the customers. It is much better engineering, and much greater economy is ob-

Digitized by Google

tained, if the question of auxiliary steam plants for a water power is met boldly and adequate provision is made for it in the beginning. The purpose of this memorandum is to suggest a convenient method for determining with accuracy the best development for a water power and the best combination that can be made with an auxiliary steam plant. The method can be used also to determine the best combination that can be made of existing steam or other power plants, and the manner in which all these factors are affected by changes in interest rates and the cost of coal, labor, supplies, etc.

The Most Economical Water Power Development. In the case used as an illustration, it is clear that if the power required exceeds 10,000 kw., the water power should be developed rather than a steam plant constructed, and this development can be carried to 25,000 or 30,000 kw. before the question of an auxiliary steam plant arises. Every water power development should be so designed that its maximum economical capacity can be conveniently developed without reconstruction, and it is important that this capacity should be determined when the original designs are made.

In the problem used as an illustration, the supplementary or auxiliary steam plant is located at the point where fuel can be obtained most economically. The analysis is based upon the annual cost of production, rather than upon earnings, for the reason that gross receipts should be approximately the same, independently of the manner in which the power is produced. We are concerned, therefore, with the single matter of ascertaining the manner in which the power can be produced at the lowest cost.

An inspection of the formulas on page 537 shows that they are materially different in the distribution of costs, and it is evident that the costs can be combined so as to obtain the point where power is produced at a minimum cost. The formulas at 100 per cent load factor, 3 per cent interest, coal at $1 per ton, and with power delivered to the low voltage distribution system, are as follows:

Water Power:	Capital cost,	$172,250 + 3.5010 per kw.	(C)
	Operation,	30,270 + 1.5746 per kw.	(E)
Steam Plant:	Capital cost,	$ 47,280 + 3,4010 per kw.	(D)
	Operation,	65,590 + 10.8528 per kw.	(F)

As it is assumed that the water power plant will be developed beyond the minimum flow, any increase in the installed capacity

Digitized by Google

in the water power plant will require a corresponding increase in the capacity of the auxiliary steam plant, so the increase in capital cost in both plants must be offset by the saving effected, and the water power can be extended until the net result is zero. This minimum point is shown at 80,000 kw. in Fig. 3. The point of minimum cost can be determined by differentiation, but is most easily obtained by a direct estimate of costs at several points. This point of minimum cost, however,

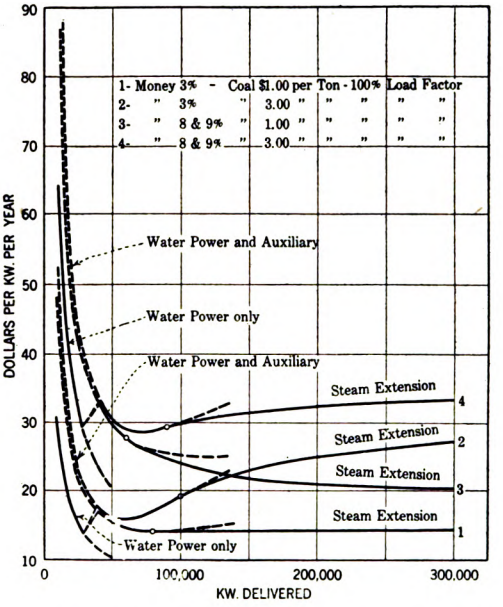


FIG. 3—LOCI OF MOST ECONOMICAL COMBINATION OF WATER POWER AND STEAM PLANTS

is not the determining factor in deciding upon the capacity to which a water power should be developed.

The Most Economical Combination Development. When the steam plant is larger than the water power, the water power is used to supplement the steam plant when and as the water power is available. In this case the capital charges of the steam plant need not be considered, and the increase in the development of the water power must be justified by the saving in the operating costs of the steam plant, and the development of the water power should be stopped where the saving resulting from such

Digitized by Google

extension amounts to zero. This relationship is expressed as follows:

$$3.501 + 1.5746X - 10.8528X = 0.$$

$$X = \frac{3.501}{9.2782} = 0.378 \times 365 = 138 \text{ days.}$$

From flow sheet Fig. 1, 138 days' operation = 80,000 kw.

Under the conditions assumed, therefore, the water power can be developed in connection with a steam plant to the point where it utilizes the flow of the stream for 138 days, which corresponds in the present case to the development of the water power to 80,000 kw. (See Fig. 3.) It is merely a coincidence that the best points for the water power and for the combination plants happen to be the same in this case.

Effect of Change in Conditions. In the contemplated construction of a water power plant, it is impossible to foretell with certainty just when conditions will change, and how much that change will be. Within the limits of probability, however, possible changes in conditions should be given careful consideration in the design and construction of the power plants. The formula method of solving these problems permits other conditions than those assumed to be readily studied and the power plant designed to meet such possible contingencies.

In the case here used as an illustration, if the rate for money is increased from 3 per cent to 8 per cent for the water power and to 9 per cent for the steam plant, to cover interest, taxes and amortization, and coal increased in cost from $1.00 per ton to $3.00 per ton, the following tables show the effect of these changes on the most economical development for a water power for operation in combination with a steam plant under the conditions assumed.

POINTS OF ECONOMICAL DEVELOPMENT

3 per cent. Money; Coal $1.00 to $3.00 per Ton

	Water power and steam auxiliary		Combination of water power and steam plant	
	Days of utilization	Kw. installed	Days of max. flow	Kw. installed
Cost of Coal:				
$1.00 per ton.....	138	80,000	138	80,000
3.00 " "	258	60,000	52	100,000

Digitized by Google

Under the condition that interest, taxes and amortization cost 8 per cent for the water power and 9 per cent for the steam plant, the points of economical development become as follows:

8 per cent. and 9 per cent. Money; Coal $1.00 to $3.00 per Ton

	Water power and steam auxiliary		Combination of water power and steam plant	
	Days of utilization	Kw. installed	Days of max. flow	Kw. installed
Cost of Coal:				
$1.00 per ton.....	365	130,000	276	56,000
3.00 " "	185	71,000	102	88,000

In the above, with coal at $1.00 per ton and money at 8 per cent and 9 per cent, it is not financially practicable to develop the water power. In the other cases assumed, the development of the water power is feasible and profitable. These results are plotted in Fig. 3.

The cost of coal will remain low, as the contemplated steam plant is assumed to be located immediately at the coal mines. The price of coal will tend to rise, however, and this fact must receive consideration in the design of the power plants. The tendency of money rates will probably be downward as the country increases in wealth. An examination of the above tables and the curves shown in Fig. 3 indicates clearly that, under the conditions assumed, the power plant should be designed for an ultimate extension to 100,000 kw., and that under the probable changed conditions, as stated, it will not be advisable to exceed this amount.

Suggested Special Power House Design. In this connection, although it is removed from the purpose of these notes, I wish to suggest a power station design which may be of use in the development of water powers with low operating heads. Direct-connected water-wheel generators are now generally used in hydroelectric developments, but when the head is low, these generators become costly on account of the low speed and the large volume of water to be passed through them. The generators must have relatively small capacity as compared to those used in steam practise. Where the power development is large, the result is that the power house building and founda-

Digitized by Google

tions, as well as the water wheels and generators, become serious factors in the cost of such a power development. In the case used as an illustration, the power station must be from one-quarter to one-half mile in length, according to the size of the generating unit used, and this is a serious factor in the cost of development. In the accompanying drawing, Fig. 4, the suggestion is made to place a simple protecting building over the

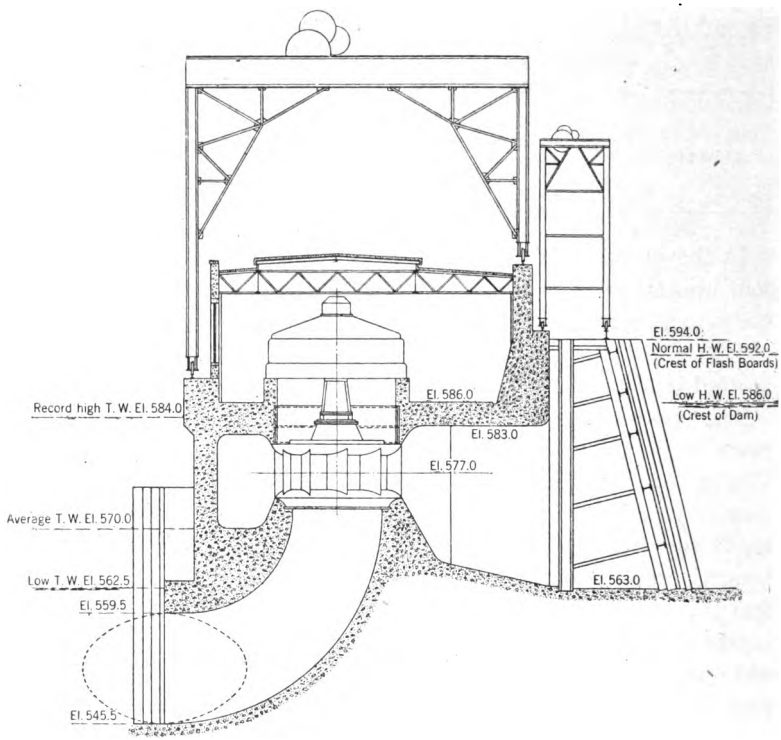


FIG. 4—CROSS SECTION OF POWER HOUSE—MISSISSIPPI RIVER POWER DEVELOPMENT—ROCK ISLAND RAPIDS

operating room and to place the switching gear, transformers, etc. in a substation building on shore, the power house being used simply as a generator room. Instead of building a high and costly structure to support and contain the crane, an external gantry crane is used and the apparatus in the station is reached through removable transoms in the roof. This method of design greatly reduces the cost of the power station construction.

Digitized by Google

There are obvious objections to reaching the apparatus through transoms, especially in bad weather. But a unit out of commission is but a small proportion of the total, and during a large part of the year there are many spare units. It is believed that the reduction in the cost more than offsets any possible inconvenience in making repairs.

Load Factor. The effect of a reduction of the load factor below the 100 per cent used in this illustration will be to increase the number of days per year during which a water wheel must be operated in order to justify its installation. On the other hand, if pondage is available above the dam, the kilowatt capacity which can be installed will be increased. The object of this paper is to indicate a method of solution for such problems, rather than to solve the various problems connected with water power developments. The necessary changes are readily made to adopt the formulas to any load factor desired. The method of solution is then the same as has been used. The kilowatt capacity curve on the flow sheet must be reconstructed to adapt it to the storage capacity which may be available above the dam.

Reserves. The reserve generating units for obvious reasons should be placed in the steam plant. An entire spare circuit should be provided in the transmission line as a reserve, and a reserve set of transformers should be provided in the substation. These reserve factors will appear as constants in the formulas expressing costs, and hence do not enter into the problem of the determination of the most economical development of the water power.

Other Uses of Formulas. Formulas such as have been shown can be developed for water powers of high head, and also where storage reservoirs are available. The capacity that can be economically installed in such developments is frequently much above preconceived conceptions. Similar formulas can be developed for existing power plants of various kinds and efficiencies, and one of the most satisfactory results of a study of the possible combinations of such plants is, that unless the apparatus installed in a plant is unusually inefficient, practically all plants have their economical place and can be efficiently used. In extreme cases, however, the resulting economy is negligible. The formulas can be used to determine whether it is best to change the frequency of a generator or to use frequency changers to obtain the desired result; also whether it is better to change an inefficient generator for a more efficient generator or to use

Digitized by Google

the inefficient generator on the peak. The solution of this problem gives the peak the generator should be allowed to carry and beyond which it should not be operated. In fact, these formulas can be used in determining practically all questions of power house design and operation which confront the designing and operating engineer. With the costs expressed in this form, the estimates of cost at other load factors and under changed conditions are quickly and readily made, and with the assurance that they are correct, for, in the last analysis, they are but interpolation, or pro rating, formulas obtained from established costs.

Financial Efficiency

Financial efficiency might be defined as the greatest earning power of a dollar. This may or may not be a controlling factor in a water power development, although it is believed that as a matter of good policy it should not be. It is conceivable, for instance, that in the long run, it might serve better in an initial development to earn 10 per cent on $200,000 than to earn 20 per cent on $100,000. Besides, the excess profit tax list might be the only beneficiary of the higher rate of return. The present notes, however, are concerned only with the explanation of a method to determine the best point of development, although this may not be the point where the dividend rate is the largest on the investment. It determines the point, however, where the enterprise is safe from competition, for the reason that the cost of production is a minimum.

By-Product Plants

It is feasible to use gas instead of coal in the production of power in the auxiliary steam plant. In most cases gas can be burned under boilers with better results than in gas engines, on account of the low cost and high efficiency of the modern steam turbine. It is now possible to obtain from all bituminous coals, whether coking coals or not, by-products of great value, by the use of either producer gas or coking plants. In many cases the sale of the by-products will pay all the costs of the by-product plant, including the cost of coal. The gas for use in the steam power plant will be a surplus product, or an additional profit, which can be added to the profits of the enterprise. Such by-product plants should receive careful consideration in the design of such a power system as is here described.

Digitized by Google

Conclusion

From the above results, several general propositions can be laid down as to the development of water powers.

Where a market for the power is available or can be created, practically all water powers should be developed beyond the minimum power available, and hence all water power plants require steam plants in connection with them.

Water power plants are most valuable when developed in connection with steam plants, and the development should be carried to the point where the best results can be obtained in combination with such steam plants.

The point of economical development of the water power is increased in capacity as the operating costs of the steam plant are increased, such as are due to the increased cost of fuel and labor.

The point of economical water power development is decreased as the value of money increases. This is true in general, although there are exceptions in the case of water powers with high heads.

The general tendency of coal and labor and other items entering into the operating cost of a steam plant is upward, and as the world increases in wealth the tendency in the value of money will be downward. These factors should be kept in mind in planning the development of a water power and adequate provision should be made for the possible extension of its capacity.

The increase in the efficiency of steam turbines and the construction of steam plants at the coal mines both operate to make it difficult to profitably develop water powers, especially those with low head, where the first cost is relatively high. The development of all possible water powers should be encouraged, both for the conservation of the fuel supply and the economical advantage resulting from the use of power in our industries. It is, therefore, important that all rights essential to the development of water power and transmission projects should be given power companies, to the end that the cost of development should be reduced and many serious difficulties now encountered removed. Any policy under which additional burdens are imposed upon water power developments, whether by the government or other authority, is against the true interests of the public and contrary to the best utilization and preservation of our natural resources. On the contrary, if a plan could be

Digitized by Google

devised so that government funds at low interest rates could be used for such developments, similar to the plan used in the construction of the New York subways, the development of water powers would be greatly facilitated and the financial values created would react to the great advantage of the government.

Digitized by Google

REPORT OF THE BOARD OF DIRECTORS
FOR FISCAL YEAR ENDING APRIL 30, 1917

The Board of Directors of the American Institute of Electrical Engineers presents herewith to the membership, its Thirty-third Annual Report for the fiscal year ending April 30, 1917. A General Balance Sheet showing the financial condition of the Institute on April 30, 1917, together with other detailed financial statements is included herein.

The Board has endeavored, as in the past, to keep the membership informed of its proceedings and of the work of the Institute, by publishing monthly in the PROCEEDINGS a resumé of the business transacted at each Directors' meeting. These notices, however, are not a complete report of the work done by the Board at any one meeting, for the reason that important matters are constantly arising which cannot be disposed of at once, and which must therefore be held over for future consideration. Publicity in such cases must frequently be deferred, but eventually full information is given to the members in subsequent issues.

Directors' Meetings.—The Board of Directors held ten meetings during the year. Five of these were held in New York City, and five were held in other cities as follows: June, in Cleveland, Ohio, during the Annual Convention; October, Philadelphia, Pa.; December, Boston, Mass.; January, Pittsburgh, Pa.; March, Chicago, Ill. Heretofore it had been the custom to hold the directors' meetings in New York on the same date as the monthly Institute meeting. When it was decided last fall to hold some of the monthly meetings outside of New York, it was also decided that the Board of Directors should meet in the city in which the Institute meeting was held, and this plan has been carried out.

In addition to the directors' meetings, the Executive Committee held three meetings. Two of these were held on February 6 and 9, 1917, respectively, for the purpose of preparing and issuing to the membership, a circular and data sheet for classifying the availability of Institute members for military or naval service in case of need. The third meeting was held on March 26, 1917. At this meeting the President was authorized to appoint a committee to consider all matters in connection with the Institute's relation to national defense, including coöperation with the various governmental departments.

National Meeting.—The Institute's Annual business meeting, on May 16, 1916, was a truly National meeting, as it was held simultaneously, by means of the long distance telephone, in Boston, New York, Philadelphia, Atlanta, Chicago and San Francisco; each person in each of the six audiences being provided with a receiver and thus being enabled to hear all that was said by the speakers in all six cities. The object was to commemorate the achievements of Institute members in the fields of communication, transportation, light and power. A message of greeting was read from the President of the United States and greetings were exchanged by the various assemblies. The meeting concluded with the adoption of the following resolution:

> RESOLVED, that this National Meeting, of the American Institute of Electrical Engineers in Boston, San Francisco, Atlanta, Chicago,

Digitized by Google

Philadelphia and New York now assembled, does hereby express its deep appreciation of the efforts of all those who have coöperated in the holding of such a meeting, which is now for the first time held in any country; and that a record of the proceedings of this meeting, which is made possible by the inventive genius and by the engineering ability of its own membership, be spread upon the minutes of the Institute, where, for generations to come, it will serve as an inspiration to engineers everywhere, and will mark an epoch in the history of American engineering achievement.

The attendance in the cities in which the meeting was held was as follows: Boston 900; New York, 1100; Philadelphia 850; Atlanta 500; Chicago 1000; San Francisco 750.

Annual Convention.—The thirty-third Annual Convention was held in Cleveland, Ohio, June 27-30, 1916. The total registered attendance was 607, of which number 319 were from out of town, twenty-two states being represented. The program consisted of seventeen technical papers on a variety of timely engineering subjects. The usual conferences of the Section Delegates were held, at which all of the Sections were represented, and a conference was also held, for the first time, of representatives of the Student Branches.

Pacific Coast Convention.—The Pacific Coast Convention was held in Seattle, Washington, September 5-9, 1916. Nine technical papers were presented and the total registration numbered 182.

Midwinter Convention, New York.—The fifth Annual Midwinter Convention was held at Institute headquarters in New York, February 14-16, 1917. The total registered attendance was 712. In addition to the eleven technical papers presented, a lecture on Modern Physics was delivered by Professor R. A. Millikan, President of the American Physical Society, and Professor of Physics of the University of Chicago. The convention closed with a subscription dinner-dance at the Hotel Astor on February 16 which was attended by 329 members and guests.

Monthly Institute Meetings.—The present year marked a change in the policy of holding monthly Institute meetings in New York. It had been the custom for many years to hold regular monthly meetings at Institute headquarters, with an occasional special meeting outside of New York under the auspices of one of the Sections, in addition to the regular New York meeting. At the beginning of the present administrative year in August 1916, President Buck expressed the opinion that the time had come to make a change in the policy of holding all of the monthly meetings in New York City, and declared himself in favor of distributing the meetings. This plan was given a trial, with the result that four of the monthly meetings were transferred from New York; one each being held in Philadelphia, Boston, Pittsburgh and Chicago. Another meeting was scheduled to be held in Schenectady in April, but it was found necessary to cancel this meeting. The meetings were largely attended, and the local officers and members were unremitting in their efforts to make them a success. A brief record of the out of town meetings follows:

Philadelphia Meeting.—The Philadelphia meeting was held on October 13, 1916. There were two technical sessions at which four papers were presented and the total registered attendance was 333.

Digitized by Google

Boston Meeting.—The Boston meeting was held on December 9, 1916. The Institute's technical session, at which two papers were presented, was held in the afternoon. The evening session was devoted wholly to the presentation of the John Fritz Medal to Professor Elihu Thomson. The attendance was about 400.

Pittsburgh Meeting.—The Pittsburgh meeting was held in Pittsburgh, Pa., on January 12, 1917. This meeting was limited to one technical session at which one paper was presented. Four hundred and twenty-five members and guests were present.

Chicago Meeting.—The Chicago meeting was held on March 9, 1917. Two papers were presented at the single technical session, and the attendance numbered 300.

New York Meetings.—A meeting was held in New York at Institute headquarters on November 10, 1916, at which three technical papers were presented. A three day Midwinter Convention was held in February as referred to elsewhere herein. The Annual Meeting on May 18, 1917, will also be held in New York.

Joint Session A. I. E. E. and A. I. & S. E. E.—A joint session of the A. I. E. E. and the Association of Iron and Steel Electrical Engineers was held during the tenth Annual Convention of the Association in Chicago on September 20, 1916. Two papers on subjects of mutual interest to the two organizations were presented on behalf of the Institute.

President.—President Buck presided at the Institute meetings held during his administration in Philadelphia, New York, Boston Pittsburgh and Chicago. He also attended the Pacific Coast Convention held in Seattle, September 5-9, 1916, the Annual Banquet of the Pittsburgh Section on December 9, 1916, the meeting of the Philadelphia Section held on February 12, 1917, and he represented the Institute at the Annual Dinner of the Providence Engineering Society March 28, 1917.

National Defense.—The Institute has continued to contribute its services to the government in the cause of preparedness and National Defense during the past year, and is now in touch with various governmental agencies through representation on committees and other bodies which are carrying on effective work for the national welfare. A brief summary of the more important activities in which the Institute is interested and in which it has taken a conspicuous part is contained elsewhere in this report.

Early in February 1916, the Executive Committee of the Institute met in special session, at which it was decided to issue to the membership a circular calling attention to the opportunities for patriotic service existing in the Army and Navy of the United States and enclosing therewith a data sheet for the purpose of tabulating the availability of members of the Institute for such service. This circular and data sheet were issued under date of February 8, 1917, and met with a very cordial response, the number of data sheets received in reply exceeding 2,000. A considerable number of the members who have sent in these sheets have been communicated with by the branches most urgently in need of the services available, and the remainder are being held for future reference.

On April 2, 1917, the Institute in cooperation with other engineering societies issued to its membership two pamphlets containing as complete

Digitized by Google

information as could be obtained for members of the engineering profession who contemplated offering their services in the army and navy. These pamphlets have resulted in the filing of many applications by Institute members for commissions in the various ranks of the Officers Reserve Corps of the army, and in the Naval Reserve.

The Executive Committee met again on March 26, 1917, for the purpose of authorizing the President to appoint a Committee on National Defense, to consider all matters which would naturally come within the scope of such a committee, and including continuation of the work formerly carried on by the Institute's representatives upon the Joint Committee on Engineer Officers' Reserve Corps. This committee was subsequently appointed by President Buck and has since been active in carrying on special work relative to National Defense.

Council of National Defense.—As the result of the act of congress of August 29, 1916, the Council on National Defense was organized for the coördination of industries and resources of the United States for the national security and welfare. The Council is made up of the Secretary of War (Chairman), the Secretary of the Navy, the Secretary of the Interior, the Secretary of Agriculture, the Secretary of Commerce and the Secretary of Labor. The act further provided for the appointment by the President, of an Advisory Commission of seven members. The Advisory Commission was subsequently appointed and is now serving the Council in a consulting capacity without compensation. The Institute was invited to appoint two representatives upon the Committee on Science and Research of the Advisory Commission, to which the supervision of engineering matters had been assigned. The Engineering Section of this committee is made up of two respresentatives each of the four national engineering societies and certain other engineering societies.

National Research Council.—The National Research Council was created by the National Academy of Sciences at the request of the President of the United States during the latter part of 1916. The object of the Council is to bring into coöperation, existing governmental, educational and other scientific and research organizations, with the purpose of encouraging investigations of natural phenomena, the increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the National Defense, and such other applications of science as will promote the national security and welfare. The work of the National Research Council is carried on through the agency of central committees covering each of the physical sciences and chemistry, mathematics, medicine, hygiene, agriculture, and other subjects, including a Committee on Engineering. To this Committee on Engineering each of the National Engineering Societies was invited to appoint two representatives and these representatives, with the engineers who are members of the Council, constitute the Committee on Engineering.

United Engineering Society.—Important changes have taken place in the affairs of the United Engineering Society during the year. On June 23, 1916, the Board of Direction of the American Society of Civil Engineers adopted resolutions accepting an invitation from the United

Digitized by Google

Engineering Society, to enter into the fraternity of the founder societies and take up their headquarters in the Engineering Societies Building. Active negotiations with the object of bringing about this result had been carried on by the A. S. C. E. and the U. E. S. for about one year prior to the action referred to above. Full details of the arrangement finally agreed upon and a memorandum of the agreement entered into will be found in the September 1916 PROCEEDINGS. As will be seen from this agreement, in order to provide suitable quarters for the A. S. C. E., it was necessary for the United Engineering Society to contract for the addition of three stories to the Engineering Societies Building. This work is now progressing satisfactorily and it is expected that the American Society of Civil Engineers will move its headquarters into the building before the end of the present calendar year, thus bringing under one roof the headquarters of the National Societies of Civil, Mining, Mechanical and Electrical Engineers, with all the obvious advantages for closer coöperation of the entire engineering profession.

Engineering Council.—The Engineering Council is the outcome of several independent movements which took definite shape early during the present year. For a long time individual engineers and the engineering societies have had in mind the desirability of having some properly constituted organization empowered to speak in the name of engineers in general upon subjects of common interest to engineers and to the public. The need of such an organization in the interest of coöperation and uniformity of action on matters relating to the welfare of the engineering profession was brought to the attention of the Board of Directors of the Institute at its meeting held in Philadelphia in October 1916, at which the subject was discussed at considerable length. A resolution was adopted at that meeting authorizing the President to appoint a committee of five members of the Board and to invite the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Institute of Mining Engineers, to appoint similar representatives upon a joint committee with a view to formulating some plan of action for organizing such a central body. A series of conferences of the representatives appointed as a result of this action followed, and after considering numerous suggestions the conferees formulated a plan to amend the by-laws of the United Engineering Society so as to provide for a new department of that Society, to be known as The Engineering Council. These amendments were subsequently approved by the four founder societies which constitute the United Engineering Society, and the Council is now being organized. The object of the Council as expressed in the amended by-laws is "to provide for convenient coöperation between the four founder societies, for the proper consideration of questions of general interest to engineers and to the public and to provide the means for united action upon questions of common concern to engineers. The Council will be maintained and conducted independently of the other activities of the United Engineering Society. Under the plan as adopted, each of the four founder societies is entitled to five representatives upon the Council, these representatives to be designated by the governing body of each society, and the United Engineering Society will have four representatives chosen by its Board of Trustees, such representatives to be men not

Digitized by Google

already designated by any of the founder societies. The Council will be empowered to speak authoritatively for all member societies on all public questions of common interest or concern to engineers unless objection be made by a majority of the representatives present of one of the founder societies or one-quarter of the representatives present and voting. The Trustees of the United Engineering Society will have authority to elect to membership in the Engineering Council, other national engineering or technical societies under such rules as the Council prescribes, provided their nomination and the said rules have the unanimous approval of the governing bodies of the four societies.

Representatives.—The Institute has continued its representation upon various national committees and other local and national bodies with which it has been affiliated in past years, and in addition has appointed representatives upon a number of new bodies including several relating to National Defense. A list of these will be found published in each issue of the PROCEEDINGS.

Committees.—There has been very little change in the character of the committees during the year. Last year a committee was appointed to formulate a plan for reorganization of the technical committees. This committee reported in August 1916 recommending a reclassification of the technical committees and the appointment of two new committees; one on electrical machinery, and one on instruments and measurements. When this report came before the Board for final consideration at the October meeting, it was decided to defer action on the reorganization of the committees, but a number of them were renamed in accordance with recommendations contained in the report so as to cover their respective fields more comprehensively.

A change in the manner of reporting upon the work of the technical committees was recently effected upon the recommendation of the Meetings and Papers Committee, through an amendment to the Institute's by-laws, under which all technical committees are now required to submit an annual report of their work at the Annual Convention. Brief reports of the technical committees have previously been included in the Annual Report of the Board of Directors, but in accordance with this change the reports of the technical committees covering the present year will be presented at the Annual Convention in June.

Meetings and Papers Committee.—The Meetings and Papers Committee arranged the programs of Institute meetings and conventions held during the year.

At the suggestion of President Buck, and with the approval of the Board of Directors, the experiment was tried of holding a number of the regular monthly meetings of the Institute in cities outside of New York. Reference to this plan and details regarding the meetings held, may be found elsewhere in this report. The object of this geographical distribution of the regular monthly meetings was to afford members at various central points a better opportunity to be brought into contact with the Institute activities. It is believed that this distribution of meetings has greatly stimulated the Sections where the meetings were held and that the Institute as a whole has been benefited.

Upon the committee's recommendation, a new by-law was adopted by

Digitized by Google

the Board of Directors providing that each technical committee shall present, at the Annual Convention, a report of the work accomplished by the committee during the year, and giving plans and suggestions for future activities. The committee believes that this by-law will be helpful in bringing about a continuity of ideas, and will be the means of increasing the usefulness of the technical committees.

The by-laws as amended in May, 1916, have established a clear distinction between the work of the Meeting and Papers and Editing committees, the former now having jurisdiction over the selection of papers to be presented, and the publication of the PROCEEDINGS, while the editing of papers and the selection of material for the annual TRANSACTIONS is now solely within the province of the Editing Committee.

Owing to unusual and unexpected demands on the finances of the Institute, the amount which could be appropriated for publication of the PROCEEDINGS and TRANSACTIONS has been somewhat reduced. This has made it necessary to exercise unusual care in the selection of material for presentation and publication. It is hoped that the work has been done in such a way that there has been no curtailment in the usefulness of the Institute to the membership.

Sections Committee.—The activities of the Sections reflect a gain over the previous year of about the usual magnitude. In view of the many unusual demands made upon the engineers in this period, this continued progress is gratifying.

No new Sections have been formed this year, but recent agitation in this direction in two or three localities, points to definite developments in the near future. The Toronto Section has resumed its activities in the face of unusual obstacles.

Continued interest manifested in the affiliation of Sections with other technical societies has resulted in the appointment of a special committee to report on such relation at the next delegates' meeting.

BRANCHES.—Perhaps the must notable item of the year is the growth of interest in the work of the Student Branches, which has been recognized by the appointment of a special Committee on Institute Branches, a subcommittee, with its chairman as vice-chairman of the Sections Committee.

This committee has already projected a lecture circuit for the Branches in the middle west, to be inaugurated next fall. The committee hopes to obtain the services of notable engineers without unreasonable demand upon their time. If this plan proves successful, other circuits will be established in localities where Branches are so grouped that such circuits are practicable.

The number of Student Branches has been raised to fifty-nine by the addition, during the year, of those newly organized at Norwich University, Vermont, University of North Dakota, University of Minnesota, Alabama Polytechnic Institute and the Massachusetts Institute of Technology. The activities in the Branches show increases corresponding to those of the Sections, while future growth should be materially favored by the improved organization.

A tabulated table showing the activity of the Sections and Branches during the past five years follows:

Digitized by Google

	For Fiscal Year Ending				
	May 1 1913	May 1 1914	May 1 1915	May 1 1916	May 1 1917
SECTIONS					
Number of Sections	29	30	31	32	32
Number of Section meetings held	244	233	246	251	265
Total Attendance	22,825	22,626	23,507	28,553	31,299
BRANCHES					
Number of Branches	47	47	52	54	59
Number of Branch meetings held	357	306	328	360	368
Attendance	11,808	11,617	12,712	15,166	16,107

Standards Committee.—The 1916 edition of the Standardization Rules was approved by the Board of Directors at the Cleveland Convention, June 28, 1916. This edition does not differ radically from the previous edition, but involves material changes in over 100 sections, with ten new sections.

Of particular value in this revision of the Rules has been the very cordial coöperation of the British Engineering Standards Committee, which was represented at the final meeting of the Standards Committee on May 15 and 16, 1916, by its Secretary, Mr. C. le Maistre, who came from London to New York for this express purpose. The By-Laws of the Standards Committee referred to in the last Annual Report were approved by the Board of Directors on June 28, 1916.

The work of the present committee has been carried on with the aid of 36 sub-committees which report at the monthly meetings of the main committee. The membership of the sub-committees is only partly confined to the main committee although the sub-committee chairmen are always members of the main committee.

The changes and additions to be proposed as a result of this year's work are for the most part not radical, and to avoid the cost of a new edition, will be printed as a supplement. It seems desirable to the committee that a new edition should not be issued oftener than once in two years.

Work is now under way by the sub-committee on "The Form but not the Substance" looking towards a complete rearrangement and standardization of typography for the 1918 Edition.

Each year the need of more effective machinery of coöperation with the standards committees of other societies has become more evident. The invitation issued at the suggestion of the Standards Committee, by the Board of Directors last winter to the A. S. C. E., the A. S. M. E., the A. I. M. E. and the A. S. T. M., each to appoint three representatives on a joint committee with the A. I. E. E., to consider the organization of a National or American Engineering Standards Committee, has met with cordial response, and the organization committee after a winter's

Digitized by Google

work is about ready to report. The chairman of the Standards Committee is chairman of the organization committee above referred to.

Another joint conference committee on standards largely within the electrical field is already in operation; it includes the A. I. E. E., the N. E. L. A., the Electric Power Club, Association of Edison Illuminating Companies., the American Electric Railway Association, the Association of Iron and Steel Electrical Engineers, the Railway Signal Association, Soc. Automobile Engineers, Institute of Radio Engineers, Illuminating Engineering Society, the American Society for Testing Materials, and the Association of Railway Electrical Engineers.

The future of this committee will depend somewhat upon the form of organization of the American Engineering Standards Committee; but whether or not it continues in its present form, it has already served and will continue to serve a very useful purpose until the broader committee is fully organized and ready to undertake its work.

Our Standardization Rules have been translated into French and this translation is now being revised by a committee including several of our French confreres, with Mr. C. O. Mailloux as chairman.

Committee on the Development of Water Power.—The committee has had no opportunity during the past year to obtain action on matters of legislation affecting water power, and has therefore confined its activities to two specific utterances on the general subject.

In the latter part of October 1916, with the approval of the Board of Directors of the Institute, the committee prepared and submitted to the Secretaries of War, Agriculture and the Interior a declaration of principles governing water power.

The second matter referred to was a letter written to the Council on National Defense, dated February 23, 1917, bringing to the Council's attention the importance of legislation in respect to Niagara Falls, and setting forth the intimate and vital relation between the products there manufactured, and national defense. This document the committee believes was of value in aiding the legislation later enacted by congress whereby the diversion of additional water at Niagara Falls was permitted up to the limits of the existing treaty.

U. S. National Committee of the International Electrotechn cal Commission.—A general meeting of the U. S. National Committee of the International Electrotechnical Commission with the Standards Committee of the A. I. E. E. was held in New York on May 12, 1916, on the occasion of the visit to the United States of General Secretary C. le Maistre. The question of graphic symbols was discussed at this meeting and referred to a sub-committee of the Standards Committee for examination. Hopes were expressed for the active resumption of the work of the Commission after the world's peace shall have been restored. The Annual Report of the Honorary Secretary of the I. E. C. for the year ending December 31, 1916 was received in January and distributed among the members of the U. S. National Committee. From the report it appears that notwithstanding the continuance of the world war very appreciable contributions to the work of the I. E. C. have been maintained by a number of the individual countries.

Pan American Joint Engineering Committee.—This committee was organized in February 1916 upon the initiative of the Institute with the

Digitized by Google

object of increasing and broadening the influence and usefulness of the national engineering societies of the United States in Central and South American countries. In addition to the Institute, the National Societies of Civil, Mining, and Mechanical Engineers are represented upon the joint committee. Preliminary meetings were held on March 3 and March 24, 1916, and on April 10, 1916, a formal organization was effected. Letters were sent to all South and Central American representatives at Washington and to the representatives of the United States in Central and South America in order to obtain the names of representative engineering organizations in those countries. These names having been obtained, a formal request was sent to the leading engineers and technical associations in each country asking their cooperation with the joint committee. The committee expects to continue this work through correspondence with the view to developing friendly relations and effecting coöperation with the engineers of Central and South America, and later may make an effort to arrange for a public meeting to stimulate interest in the movement among the engineers of the United States.

Code Committee.—The Code Committee has continued to represent the Institute on the Electrical Committee of the National Fire Protection Association. Several sub-committee meetings on various subjects have been held during the year, and the Institute has been represented by one or more members of the Code Committee at each of such meetings.

Editing Committee.—Under the revised Constitution adopted last year, the Editing Committee has entire supervision of the annual TRANSACTIONS of the Institute, and receives an annual appropriation for carrying on this work independent of the monthly PROCEEDINGS, which are now in sole charge of the Meetings and Papers Committee. Under the new regime the Editing Committee has arranged to publish the 1916 TRANSACTIONS early this summer and thereafter to publish a semi-annual volume each fall and spring covering the half-years ending June 30 and December 30 respectively. In other respects the method of handling the publications has been the same as for several years past and appears to meet with general satisfaction.

Board of Examiners.—The Board of Examiners held 13 meetings during the year averaging about three and a half hours each. It considered and referred to the Board of Directors with its recommendations a total of 2006 applications of all kinds. In addition to these, the Board reviewed or reconsidered 47 applications for a second and third time. The result of the Board's work for the year is given in the following statement:

APPLICATIONS FOR ADMISSION.

Recommended for grade of Associate	938	
Not recommended for grade of Associate	3	941
Recommended for grade of Member	67	
Not recommended for the grade of Member	33	100
Recommended for grade of Fellow	2	
Not recommended for Fellow	2	4
Recommended for enrolment as students	856	856

Digitized by Google

APPLICATIONS FOR TRANSFER.

Recommended for grade of Member	57	
Not recommended for grade of Member	21	78
Recommended for grade of Fellow	12	
Not recommended for grade of Fellow	15	27
Total number of applications considered		2006
Applications reconsidered		47
Admission and transfer all grades		2053

Membership Committee.—The Membership Committee this year included the chairman of each local Section Membership Committee and six members at large. Its work, therefore, was founded principally upon Section activity. Four meetings were held by the committee during the year.

The membership booklet containing information regarding the object, scope and work of the Institute was revised by rearranging the material, the incorporation of cuts, and including for the convenience of applicants, a tabulation of the critical facts in regard to applications. A booklet relating to Student enrolment was prepared and published.

Following the custom established by the Membership Committee of last year, the present committee cooperated with the New York office in the collection of dues from delinquent members with gratifying success.

The following tabulated statement shows the total number of applications received, also the additions, deductions, and net increase in the membership for the year. A study of these shows the direct effect of the work through the Sections, inasmuch as almost twice as many applications were received from Section territory as from outside, whereas the ratio in the past has generally been about one to one.

	Honorary Member	Fellow	Member	Associate	Total
Membership, April 30, 1916.	5	454	1137	6616	8212
Additions:					
Transferred	....	8	65	....	....
New Members Qualified	....	1	57	895	....
Reinstated	....	....	3	24	....
Deductions:					
Died	1	4	8	35	....
Resigned	....	1	7	118	....
Transferred	....	....	6	67	....
Dropped	....	....	15	293	....
Membership, April 30, 1917	4	458	1226	7022	8710

Net increase in membership during the year 498

Digitized by Google

Deaths.—The following deaths have occurred during the year:

Honorary Member.—Dr. Silvanus P. Thompson.

Fellows.—Henry Floy, William Stanley, A. C. Eastwood, Henry G. Stott.

Members.—F. C. Green, Judson H. Boughton, Charles H. Champion, F. W. Myers, Robert E. Noyes, Charles Guckel, A. C. Einstein, Joseph P. Davis.

Associates.—John W. Beyer, E. M. Barton, W. C. Janney, Nathan A. Dreyfus, John H. Wilson, Louis S. Baird, A. Nielsen, R. H. Harrison, Harold Lomas, Porter Eveland, Frank B. McSoley, G. W. Krause, M. Pfatischer, H. P. Collins, N. L. Jennings, Louis E. Reynolds, J. G. M. Connally, J. D. Simpson, J. A. Shepard, John A. Barrett, W. Schlombs; Stewart E. Padfield, Bayse N. Westcott, Arthur J. Howard, Frederic H. Reed, Robert S. Orr, Fred F. Paulsell, William Brophy, P. P. Spaulding, G. Henry Hill, George H. Usher, T. K. Arunachela-Iyer, F. W. Roebling, H. J. Bildhauser, J. H. Steele.

Total deaths, 48.

Finance Committee—The following correspondence and financial statements form a complete summary of the work of the Finance Committee of the year.

New York, May 16, 1917.

Board of Directors,
American Institute of Electrical Engineers.

Gentlemen:

Your Finance Committee respectfully submits the following report for the year ending April 30, 1917.

During the past year the committee has held monthly meetings, has passed upon the expenditures of the Institute for various purposes and otherwise performed the duties prescribed for it in the Constitution and By-laws. Haskins & Sells, certified public accountants, have audited the books, and their certification of the Institute finances follows.

In company with your Secretary, and a representative of the firm of accountants, the committee has examined the securities held by the Institute and finds them to be as stated in the accountants' report.

It is gratifying to note that notwithstanding the unusual conditions that have prevailed during the year, it has been possible to continue all the activities of the Institute without curtailment and, as indicated in the accompanying auditors' report, the financial affairs of the Institute are in a very favorable condition.

Respectfully submitted,
(Signed) J. FRANKLIN STEVENS,
Chairman, Finance Committe.

Digitized by Google

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS
CABLE ADDRESS "HASKSELLS"
30 BROAD STREET
NEW YORK

NEW YORK
CHICAGO
ST. LOUIS
CLEVELAND
BALTIMORE
PITTSBURGH

SAN FRANCISCO
LOS ANGELES
DENVER
ATLANTA
WATERTOWN
LONDON

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

CERTIFICATE

We have audited the books and accounts of the American Institute of Electrical Engineers for the year ended April 30, 1917, and

WE HEREBY CERTIFY that the accompanying General Balance Sheet properly sets forth the financial condition of the Institute on April 30, 1917, that the Statement of Income and Profit and Loss for the year ended that date is correct, and that the books of the Institute are in agreement therewith.

HASKINS & SELLS,
Certified Public Accountants.

NEW YORK,
May 12, 1917.

Digitized by Google

EXHIBIT A. AMERICAN INSTITUTE OF GENERAL BALANCE SHEET

ASSETS.

LAND AND BUILDING:		
Interest in United Engineering Society's Real Estate, No. 25 to 33 West 39th Street:		
Land (One-third of Cost)	$180,000.00	
Building	353,346.61	
Total Land and Building		$533,346.61
EQUIPMENT:		
Library—Volumes and Fixtures	$ 39,879.80	
Works of Art, Paintings, etc.	3,001.35	
Office Furniture and Fixtures	11,470.06	
Total	$54,351.21	
Less Reserve for Depreciation	8,104.78	
Remainder—Equipment		$ 46,246.43
INVESTMENTS:		
BONDS—City of Wilmington, Delaware, 4½%, 1934, Par $15,000		$ 15,886.33
WORKING ASSETS:		
Publications entitled "Transactions," etc.	$ 12,884.25	
Paper and Cover Paper	1,173.85	
Badges	647.15	
Total Working Assets		$ 14,705.25
CURRENT ASSETS:		
Cash	$ 11,291.95	
Accounts Receivable:		
Members for Past Dues	9,635.06	
Advertisers	494.20	
Miscellaneous	569.72	
Due from Societies Affiliated in National Defense Movement	653.77	
Accrued Interest on Investments	56.25	
Accrued Interest on Bank Balances	172.34	
Total Current Assets		$ 22,873.29
FUNDS:		
Life Membership Fund:		
Cash	$ 438.67	
Chicago, Burlington & Quincy Railroad Company Bonds, 4%, 1958, Par $5,000	4,868.75	
Accrued Interest	33.33	
	$ 5,340.75	
International Electrical Congress of St. Louis—Library Fund:		
Cash	$ 850.59	
New York City Bonds, 4½%, 1957, Par $2,000.00	2,255.09	
Accrued Interest	45.00	3,150.68
MAILLOUX FUND:		
Cash	$ 122.35	
New York Telephone Company Bond, 4½%, 1939	1,000.00	
Accrued Interest	22.50	1,144.85
Midwinter Convention Fund—Cash		95.80
Total Funds		$ 9,732.08
DUES PAID IN ADVANCE—INTERNATIONAL ELECTROTECHNICAL COMMISSION, LONDON, ENGLAND		750.00
Total		$643,539.99

Digitized by Google

ELECTRICAL ENGINEERS
APRIL 30, 1917.

LIABILITIES.

CURRENT LIABILITIES:		
Accounts Payable—Subject to Approval by the Finance Committee	$ 8,383.29	
Dues Received in Advance	2,097.69	
Entrance Fees and Dues Advanced by Applicants for Membership	310.50	
Total Current Liabilities		$ 10,791.48
FUND RESERVES:		
Life Membership Fund	$ 5,340.75	
International Electrical Congress of St. Louis—Library Fund	3,150.68	
Mailloux Fund	1,144.85	
Midwinter Convention Fund	95.80	
Total Fund Reserves		$ 9,732.08
SURPLUS: Per Exhibit "B"		$623,016.43
Total		$643,539.99

Digitized by Google

AMERICAN INSTITUTE OF

EXHIBIT A. GENERAL BALANCE SHEET

ASSETS.

LAND AND BUILDING:		
Interest in United Engineering Society's Real Estate, No. 25 to 33 West 39th Street:		
Land (One-third of Cost)	$180,000.00	
Building	353,346.61	
Total Land and Building		$533,346.61
EQUIPMENT:		
Library—Volumes and Fixtures	$ 39,879.80	
Works of Art, Paintings, etc.	3,001.35	
Office Furniture and Fixtures	11,470.06	
Total	$54,351.21	
Less Reserve for Depreciation	8,104.78	
Remainder—Equipment		$ 46,246.43
INVESTMENTS:		
BONDS—City of Wilmington, Delaware, 4½%, 1934, Par $15,000		$ 15,886.33
WORKING ASSETS:		
Publications entitled "Transactions," etc.	$ 12,884.25	
Paper and Cover Paper	1,173.85	
Badges	647.15	
Total Working Assets		$ 14,705.25
CURRENT ASSETS:		
Cash	$ 11,291.95	
Accounts Receivable:		
Members for Past Dues	9,635.06	
Advertisers	494.20	
Miscellaneous	569.72	
Due from Societies Affiliated in National Defense Movement	653.77	
Accrued Interest on Investments	56.25	
Accrued Interest on Bank Balances	172.34	
Total Current Assets		$ 22,873.29
FUNDS:		
Life Membership Fund:		
Cash	$ 438.67	
Chicago, Burlington & Quincy Railroad Company Bonds, 4%, 1958, Par $5,000	4,868.75	
Accrued Interest	33.33	
	$ 5,340.75	
International Electrical Congress of St. Louis—Library Fund:		
Cash	$ 850.59	
New York City Bonds, 4½%, 1957, Par $2,000.00	2,255.09	
Accrued Interest	45.00	3,150.68
MAILLOUX FUND:		
Cash	$ 122.35	
New York Telephone Company Bond, 4½%, 1939	1,000.00	
Accrued Interest	22.50	1,144.85
Midwinter Convention Fund—Cash		95.80
Total Funds		$ 9,732.08
DUES PAID IN ADVANCE—INTERNATIONAL ELECTROTECHNICAL COMMISSION, LONDON, ENGLAND		750.00
Total		$643,539.99

Digitized by Google

ELECTRICAL ENGINEERS
APRIL 30, 1917.

LIABILITIES.

CURRENT LIABILITIES:		
Accounts Payable—Subject to Approval by the Finance Committee	$ 8,383.29	
Dues Received in Advance	2,097.69	
Entrance Fees and Dues Advanced by Applicants for Membership	310.50	
Total Current Liabilities		$ 10,791.48
FUND RESERVES:		
Life Membership Fund	$ 5,340.75	
International Electrical Congress of St. Louis—Library Fund	3,150.68	
Mailloux Fund	1,144.85	
Midwinter Convention Fund	95.80	
Total Fund Reserves		$ 9,732.08
SURPLUS: Per Exhibit "B"		$623,016.43
Total		$643,539.99

Digitized by Google

EXHIBIT A. AMERICAN INSTITUTE OF GENERAL BALANCE SHEET

ASSETS.

LAND AND BUILDING:			
Interest in United Engineering Society's Real Estate, No. 25 to 33 West 39th Street:			
Land (One-third of Cost)		$180,000.00	
Building		353,346.61	
Total Land and Building			$533,346.61
EQUIPMENT:			
Library—Volumes and Fixtures		$ 39,879.80	
Works of Art, Paintings, etc.		3,001.35	
Office Furniture and Fixtures		11,470.06	
Total		$54,351.21	
Less Reserve for Depreciation		8,104.78	
Remainder—Equipment			$ 46,246.43
INVESTMENTS:			
BONDS—City of Wilmington, Delaware, 4½%, 1934, Par $15,000			$ 15,886.33
WORKING ASSETS:			
Publications entitled "Transactions," etc.		$ 12,884.25	
Paper and Cover Paper		1,173.85	
Badges		647.15	
Total Working Assets			$ 14,705.25
CURRENT ASSETS:			
Cash		$ 11,291.95	
Accounts Receivable:			
Members for Past Dues		9,635.06	
Advertisers		494.20	
Miscellaneous		569.72	
Due from Societies Affiliated in National Defense Movement		653.77	
Accrued Interest on Investments		56.25	
Accrued Interest on Bank Balances		172.34	
Total Current Assets			$ 22,873.29
FUNDS:			
Life Membership Fund:			
Cash	$ 438.67		
Chicago, Burlington & Quincy Railroad Company Bonds, 4%, 1958, Par $5,000	4,868.75		
Accrued Interest	33.33		
		$ 5,340.75	
International Electrical Congress of St. Louis—Library Fund:			
Cash	$ 850.59		
New York City Bonds, 4½%, 1957, Par $2,000.00	2,255.09		
Accrued Interest	45.00	3,150.68	
MAILLOUX FUND:			
Cash	$ 122.35		
New York Telephone Company Bond, 4½%, 1939	1,000.00		
Accrued Interest	22.50	1,144.85	
Midwinter Convention Fund—Cash		95.80	
Total Funds			$ 9,732.08
DUES PAID IN ADVANCE—INTERNATIONAL ELECTROTECHNICAL COMMISSION, LONDON, ENGLAND			750.00
Total			$643,539.99

Digitized by Google

ELECTRICAL ENGINEERS
APRIL 30, 1917.

LIABILITIES.

CURRENT LIABILITIES:		
Accounts Payable—Subject to Approval by the Finance Committee	$ 8,383.29	
Dues Received in Advance	2,097.69	
Entrance Fees and Dues Advanced by Applicants for Membership	310.50	
Total Current Liabilities		$ 10,791.48
FUND RESERVES:		
Life Membership Fund	$ 5,340.75	
International Electrical Congress of St. Louis—Library Fund	3,150.68	
Mailloux Fund	1,144.85	
Midwinter Convention Fund	95.80	
Total Fund Reserves		$ 9,732.08
SURPLUS: Per Exhibit "B"		$623,016.43
Total		$643,539.99

Digitized by Google

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

STATEMENT OF INCOME AND PROFIT AND LOSS

FOR THE YEAR ENDED APRIL 30, 1917

EXHIBIT B.

REVENUE:			
Entrance Fees		$ 5,207.00	
Dues		92,177.08	
Student's Dues		4,989.00	
Transfer Fees		705.00	
Advertising		7,162.20	
Subscriptions		3,147.55	
Sales of "Transactions," etc.		2,782.33	
Badges Sold	$2,283.00		
Less Cost	1,966.11		
		316.89	
Interest on Investments		675.00	
Interest on Bank Balances		650.33	
Exchange		31.30	
Total			$117,843.68
EXPENSES:			
Meetings and Papers Committee:			
Salaries, Editorial Department		$ 5,944.16	
Paper and Cover Paper		3,665.55	
Engraving Proceedings		1,587.49	
Printing Proceedings		6,715.61	
Binding and Mailing Proceedings		3,880.60	
Envelopes		823.44	
Stationery and Miscellaneous Printing		79.75	
General Expenses		87.18	
Meetings		5,596.98	
National Meeting, May 16, 1916		1,419.89	
Joint Meeting—American Association for the Advancement of Science		169.50	
Volume No. 33. Transactions		15.01	
Volume No. 34. "		14,514.21	
Volume No. 35. "		1,824.84	
Total		$ 46,324.21	
Deduct Increase in Inventory of Publications:			
May 1, 1916	$10,908.50		
April 30, 1917	12,884.25	1,975.75	$ 44,348.46
Executive Department:			
Salaries		$ 17,299.00	
General Expenses		2,550.81	
United Engineering Society—Assessments		4,800.00	
Express		294.54	
Postage		2,047.80	
Advertising		2,149.47	
Stationery and Miscellaneous Printing		3,516.45	
Year Book and Catalogue		3,103.32	$ 35,761.39
FORWARD			$ 80,109.85
REVENUE—(Forward)			$117,843.68

Digitized by Google

REVENUE—(Forward)		$117,843.68
EXPENSES—(Forward)		$ 80,109.85
Sections Committee:		
Section Meetings	$ 5,938.51	
Branch Meetings	183.10	
Delegates' Convention Expenses	1,436.92	
Salaries, New York Office	2,340.00	
Stationery and Printing, New York Office	672.30	
Express on Advance Copies	26.13	$ 10,596.96
General:		
Library Assessment, United Engineering Society	$ 4,000.00	
Membership Committee	1,051.44	
Finance Committee	150.00	
Standards Committee	778.52	
Code Committee	30.00	
National Defense Committee	803.24	
Pan American Engineering Committee	25.00	
Constitutional Revision Committee	73.35	
International Engineering Congress, 1915	1,800.00	
Annual Dues, International Electrotechnical Commission	250.00	
John Fritz Medal Award	109.20	
President's Special Appropriation	341.92	
Salary and Traveling Expenses, Honorary Secretary	4,421.28	13,833.95
Total		$104,540.76
Add:		
Increase in Accounts Payable—Subject to Approval by the Finance Committee, Expenses Undistributed at:		
May 1, 1916	$ 7,146.64	
April 30, 1917, not including Liability of $708.20 incurred for Account of Societies Affiliated in National Defense Movement	7,675.09	528.45
Total Expenses		$105,069.21
NET REVENUE		$ 12,774.47
PROFIT & LOSS CREDIT—Accessions to Library Volumes and Fixtures		662.50
GROSS SURPLUS FOR THE YEAR		$ 13,436.97
PROFIT & LOSS CHARGES:		
Uncollectible Dues Written Off	$ 3,051.00	
Provision for Depreciation of Furniture and Fixtures	1,329 65	
Amortization of Premium on City of Wilmington, Delaware, 4½% Bonds of 1934	52.50	
Total		4,433.15
NET SURPLUS FOR THE YEAR		$ 9,003.82
SURPLUS, MAY 1, 1916		614,012.61
SURPLUS, APRIL 30, 1917		$623,016.43

Digitized by Google

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

STATEMENT OF CASH RECEIPTS AND DONATIONS FOR DESIGNATED PURPOSES. ALSO DISBURSEMENTS, FOR THE YEAR ENDED APRIL 30, 1917.

EXHIBIT C.

RECEIPTS:	
Life Membership Fund	$365.86
International Electrical Congress of St. Louis Library Fund—Interest and Royalties	94.20
Mailloux Fund—Interest	45.00
Midwinter Convention Fund—Interest	3.16
Total	$508.22
DISBURSEMENTS:	
Life Membership Fund	277.08
Mailloux Fund	26.75
Midwinter Convention Fund	66.29
Total	$370.12

RECEIPTS AND DISBURSEMENTS PER YEAR PER MEMBER.

During each fiscal year for the past eight years.

Year ending April 30	1910	1911	1912	1913	1914	1915	1916	1917
Membership, April 30, each year	6681	7117	7459	7654	7876	8054	8212	8710
Receipts per Member	$13.35	$13.37	$13.19	$13.45	$14.08	$14.06	$13.62	$13.30
Disbursements per Member	12.03	11.03	12.44	15.57	12.86	13.54	13.74	12.75
Credit Balance per Member	$1.32	$2.34	$ .75	*$2.12	$1.22	$ .52	*$ .12	$ .55

*Deficit.

Respectfully submitted for the Board of Directors,

F. L. HUTCHINSON, *Secretary.*

New York, May 18, 1917.

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 28, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

FORMS OF ELECTRIC POWER BEST SUITED FOR THE VARIOUS LOADS ENCOUNTERED IN THE OPERATION OF BITUMINOUS COAL MINES.

BY R. L. KINGSLAND

ABSTRACT OF PAPER

The best form of power to be used in coal mines for drilling, cutting, hauling, pumping, lighting and ventilation, Synchronous converters versus motor-generator sets. Location of generating plant and substations.

THIS paper is intended to deal entirely with the practical application of electric power to bituminous coal mining.

There are two general forms of electric power available; alternating current and direct current. With alternating current we have two standard frequencies; *i.e.* 25 and 60 cycles, and with both alternating and direct current we have many standard voltages.

In the question of frequency the writer is much in favor of 60 cycles. This has become more and more the standard frequency for central stations. There used to be some advantages of 25 cycles for rotary-converter work, but this has been cut down until today the 60-cycle machine is considered the equal of the 25. This choice of 60 cycles can be further justified by noting that in selecting motors for various mine services to operate between the speed limits of 300 and 3600 rev. per min. we have the choice of 12 speeds in the case of 60 cycles and only 5 in the case of 25 cycles.

Different voltages are more easily obtained with alternating current than with direct current due to transformers. The rated voltage on a-c. machines may be misleading from a safety standpoint. This rated voltage is the effective voltage; whereas the peak, or maximum instantaneous voltage, is equal to almost one and one half times the average value. Thus a person coming in contact with an a-c. 300-volt line could receive 423 volts while with a d-c. line he could receive only 300 volts.

The question of transmission is one of the most important in

Manuscript of this paper was received June 13, 1917.

Digitized by Google

connection with coal mining. If complete copper circuits are used, 3-phase 3-wire alternating current with unity power factor requires only three-fourths the copper that direct current of the same voltage does. In actual practise, however, in bituminous coal mining work under ground, the nature of the load is such that more copper is required for a 3-phase a-c. circuit than for a d-c. circuit of the same voltage. This is largely due to the lagging power factor caused by induction motor load. It is common practise in d-c. transmission underground, to use the rail for the return circuit. In the case of 3-phase alternating current the rail may be used in place of one of the wires. In this case the total feeder wire for alternating current unity power factor and direct current would be exactly the same for the same voltage drop. Actual conditions, however, in this case require even a larger excess of copper for the alternating current than where complete copper circuits are used.

What is known as low voltage is steadily increasing in favor for portable machines used under ground. This includes a maximum voltage of 300, with a 10 per cent divergency factor allowed. In other words the actual maximum voltage at any point on the lines cannot be in excess of 330 volts to come within what is termed low voltage. For stationary machines, medium or even high voltages can be used to advantage, and safely, if proper protection is afforded.

To summarize the writer favors the use of direct current or 3-phase 60-cycle a-c. power at 330 volts or less for all portable machines under ground and considers that stationary machines should be treated individually.

When considering the separate classes of motor-driven machines it is well to keep in mind some of the principal characteristics of the most commonly used motors; *i.e.* the d-c. shunt and compound motors and the a-c. squirrel-cage induction motor. For our purposes these are all used as constant-speed motors. In the d-c. motors the speed varies almost directly with the voltage while with the a-c. the speed is practically independent of the voltage and depends on the frequency. The torque of the d-c. motors varies almost directly with the voltage, but in the a-c. induction motor the torque varies with the square of the voltage. As an example if we had one-half rated voltage on a d-c. shunt motor we would have one-half torque, while with one-half voltage on a squirrel-cage induction motor we would only have one-fourth the torque. This is a good

Digitized by Google

point to keep in mind when considering a-c. motors for portable machines under ground.

For under ground distribution only two classes of copper conductors have been found practical—bare, and lead covered steel armored. Other forms of insulation can not be depended upon for any length of time, and are therefore not as safe as no insulation.

In order to cover all classes of load each will be taken up in turn. First we will consider the under ground loads, and then the surface loads.

The machine most used for cutting coal today is that known as the chain machine. The squirrel-cage induction motor is ideal for driving this machine, provided the proper voltage can be supplied to it. Shunt or compound-wound d-c. motors are more frequently used for reasons which will appear later.

Drilling machines used for making the shot holes are made in various types, some of them being driven by the same motors that run the cutting machines, and some by separate motors. A constant-speed motor is required, and high starting torque is not necessary.

Several types of coal loading machines have been developed, but none of them have come into general use as yet. Motors for these require the same characteristics as for coal cutting machines.

Combination coal cutting and loading machines are being experimented with, but they do not appear to be even as far advanced as the loading machines. Constant-speed high starting torque motors are also required for their operation.

One of the main factors in determining the form of electric power to use under ground in large mines is haulage. No practical means has been developed for heavy haulage by the use of alternating current and we are therefore limited to direct current. Haulage may be divided into three classes; trolley locomotive, storage battery locomotive, and stationary hoist. For trolley locomotives d-c. series motors have proven by far the most practical. For battery locomotives the same is, of course, true. For stationary hoists much depends on the amount of load, the distance from power source by way of the mine workings, and the distance from the surface. More will be said of this later.

Pumps used in mines can be placed in two classes—those used for gathering the water to one or more central points, and those

Digitized by Google

used to remove it from these central points to the surface. For the smaller pumps, or those coming under the first class, it is obvious that the same form of power should be used as is used for cutting, drilling and loading. The larger pumps will be treated with stationary hoists.

Lighting under ground can be most easily accomplished by the power that is used for other purposes where the lights are required. That is, it is not worth the extra installation and maintenance expense to string separate lighting lines through a mine. In the case of shaft mines or slope mines it is some times advisable to install separate circuits for the lighting where trips of coal are landed, and where the empty trips are made up. Tungsten lamps are the most economical lamp available for the size units required under ground. It has been the writer's experience, however, that these lamps do not give satisfactory services on voltages above 125 in sizes smaller than 200 watts. For use on 250 or 300-volt service I have found the carbon filament lamp to give the best results.

For concentrated loads of 100 horse power or over such as hoists, pumps, and underground substations I have found separate lead-covered steel-armored cables leading direct from the surface through special bore holes very satisfactory for supplying alternating current at voltages up to 11,000 star. Such cables are practically indestructable. For centrifugal or plunger pump installations constant-speed induction motors of the bore hole cable voltages can be used with perfect safety as there are no exposed contacts. Hoists can be treated in the same way and where necessary current-limiting devices can be applied so as to cut down the peak load. For under ground substations it is generally advisable to transform down to the required voltage in the substation room, in case synchronous coverters are used. For motor-generator sets this is of course unnecessary.

The question of the relative merits of synchronous converters versus motor-generator sets, while not closely related to the question of selecting the best form of power, is of considerable importance to mine operators. The principal advantages attributed to the motor-generator set are higher power factor and closer voltage regulation. The advantages of the synchronous converters are lower first cost, small space occupied, and higher efficiency. The writer favors the synchronous converter because he has found that its advantages outweigh those of the motor-generator set in practise. I have operated a central plant

Digitized by Google

having a mine load only, consisting of twenty five mines, where synchronous converters were used for supplying all d-c. power, and induction motors for fans, pumps, etc.; and where the power factor was ninety eight per cent lagging on peak loads, and never went below ninety per cent. I have found that the latest design of synchronous converters will carry momentary overloads of two hundred per cent and that motor-generator sets are not good for over one hundred per cent overload. The d-c. voltage at the substations was practically constant. When installing a substation inside a mine the smaller space necessary for the synchronous converter will be found to be of great advantage. It is easier to prevent squeezes from above and below with a small room than with a large one.

In locating a pumping station the possible location of a substation adjacent to it should not be lost sight of. This often means materially better voltage conditions for cutting and hauling coal without increased labor cost. The same man can operate the substation and the pump station.

In a great many bituminous coal mines ventilation is of first importance. For this reason we should have the most reliable ventilating equipment. As the squirrel-cage induction motor is the most rugged, as well as the simplest form of electric motor made, it lends itself especially well to this class of work. Through experience I have found that this type of motor gives entire satisfaction. In cases where it is advisable to reduce the volume of air delivered to a mine for certain periods, in order to save power or for some other reason, a two-speed motor of the same type can be used to advantage. Changing the speed of the fan from time to time as mine workings progress can be accomplished by changing the pulley sizes for a belted fan or the sprocket sizes for a chain driven, or geared fan. My own opinion favors belt drives as these relieve the motor from the cut off blows of the fan. In case a-c. power is not available for fan drives shunt motors should be used, but commutators prevent their giving the same reliable service as the induction motor.

In the preparation of coal one of the principal difficulties that motors encounter is fine dust, and plenty of it. The totally enclosed squirrel cage, or where service requires it, the wound-rotor induction motor meets this condition most successfully. In either case, it is preferable to have a totally enclosed motor. Totally enclosed compound-wound motors should be used if alternating current is not available.

Digitized by Google

Shop drives and lighting can be classed together because both of these should depend on the primary source of power. They should not depend on the operation of any more machinery than is absolutely necessary. Lights will be required when everything else about a mining plant is closed down, and shop operations will also be required when all other equipment is at a stand still.

In conclusion I would say that for large mines the most practical power for the main supply would be three phase sixty cycles at a voltage high enough to reach all necessary points with a loss of not over ten per cent of the power delivered. This allows the use of a-c. motors and lights on the surface and also wherever they can be used to advantage under ground. Synchronous converters delivering 300 volts direct current can be installed on the surface and under ground, as best suits the conditions; and by their use the amount of copper required inside a mine can be kept at a minimum.

If d-c. power is generated it is not economical and often not practical to install several small generating stations. The obtaining of fuel and water often present difficulties. Therefore the d-c. power plant is generally located near the tipple. This means that power can be fed only one way to the mine. With substations located so as to feed power to the load in two directions, only about one fourth the copper is necessary for the same length of line and the same voltage drop.

For small mines where locomotive haulage can not be used to advantage, alternating current may be used to advantage for mining machines and pumps. This is especially true if alternating current is available from a central station.

Digitized by Google

To be presented at the 34th Annual Convention of the American Institute of Electrical Engineers, Hot Springs, Va., June 28, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

A NEW ELECTRIC MINE HOIST AT BUTTE, MONTANA

BY R. S. SAGE

ABSTRACT OF PAPER

A description of equipment in connection with a recent Ilgner-Ward Leonard hoist installation at the Elm Orlu Mining Company, Butte, Montana. This installation is one of the two largest of this type in operation in this country.

Complete data on two sets of tests; the first conducted to analyze a typical day's run and the second to determine efficiency while hoisting under known conditions.

GENERAL

DURING the past year and a half, a period to be remembered for its tremendous industrial activity, extraordinary progress was made in the field of mine electrification; and in particular in the electrification of mine hoists of more than average capacity and importance, and for whose operation the highest type of electrical system was demanded. This progress extended to both the coal mining and the metal mining fields.

Illustrative of the extent of this progress, it may be said that the number of Ward Leonard and Ilgner-Ward Leonard hoist equipments which will have been put into operation in this country during the two years of 1916 and 1917 will equal the total number operating prior to 1916, and the aggregate horsepower capacity will be 50 per cent greater.

A recent Ilgner-Ward Leonard hoist installation of considerable interest is that at the mine of the Elm Orlu Mining Company at Butte, Montana. This equipment has been in regular productive operation since the first week of last February having been put into commission to replace an old steam hoist at that time. This type of hoist but recently made its appearance in the Butte district, and the present installations are but forerunners of many electrifications which will undoubtedly be made in the near future.

This equipment is of interest, first, because of its capacity, it being one of the two largest of this type in operation in this

Manuscript of this paper was received June 8, 1917.

Digitized by Google

country, and, second, because of its unusual smoothness of operation, simplicity and ease of control, it being so noted throughout the Butte camp.

A series of tests under operating conditions were carried out, the results of which, together with a description of the equipment are given herein.

The hoisting equipment is installed in a very substantial brick building of one room, the motor-generator set with flywheel, the slip regulator and the switchboard occupying all of one end. Views of the hoist and motor and the power set are given in Figs. 1 and 2. The building is exceptionally well lighted, both by day and by night, and there is a particular absence of crowding and congestion. Two 20-ton* hand-operated traveling cranes provide adequate capacity for the handling of the heaviest parts.

Duty

As is well known, for the driving of large high-speed shaft hoists, considerations of accuracy of control and safety of operation necessitate the use of equipments operating on the Ward Leonard system. This system combined with a flywheel for load equalization, commonly known as the Ilgner-Ward Leonard system, is necessary wherever the conditions of power supply require it. In this instance, as for the majority of equipments of this character, flywheel equalization was imperative, as the reservation charge is based on the maximum instantaneous demand. For this reason, flywheel capacity was supplied sufficient to completely equalize the maximum duty cycle met in balanced hoisting from the deepest level.

The shaft has been sunk to a depth of 1800 ft. (548.6 m.), and ore is being hoisted regularly from the 1100, 1200, 1300, 1400, 1500 and 1800-ft. (335.2 m. to 548.6 m.) levels. Ultimately, the ore will be taken from a seam 3500 ft. (1066.8 m.), below the surface.

The general characteristics of the hoist are as follows:

Inclination of shaft with horizontal	90 deg.
Present maximum lift	1800 ft.
Ultimate " "	3500 ft.
Weight of skip and man cage	11,000 lb. (4989 kg.)
Weight of ore per trip	10,000 lb. (4535 kg.)
Weight of one rope (3500 ft.)	12,500 lb. (5669 kg.)
Maximum speed of skip during hoisting	2,500 ft. per min.
Diameter of cable	1.5 in. (38.1 mm.)
Weight of cable, per foot	3.55 lb. (1.58 kg.)

* One short ton = 0.9 metric ton.

Digitized by Google

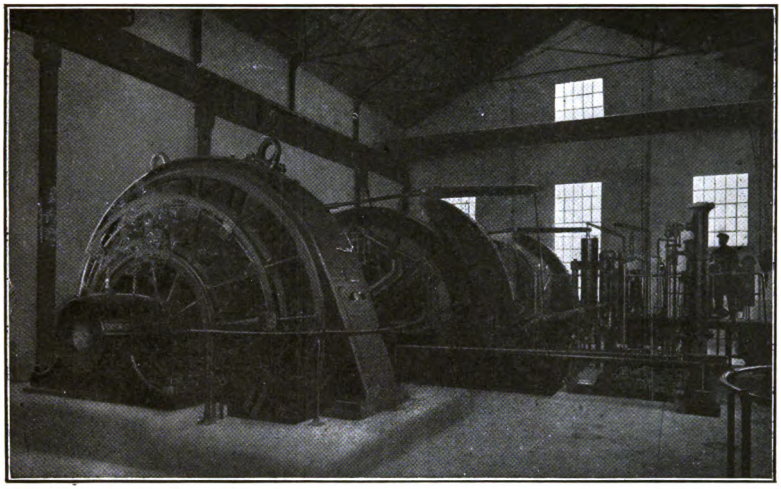


FIG. 1—VIEW OF HOIST MOTOR

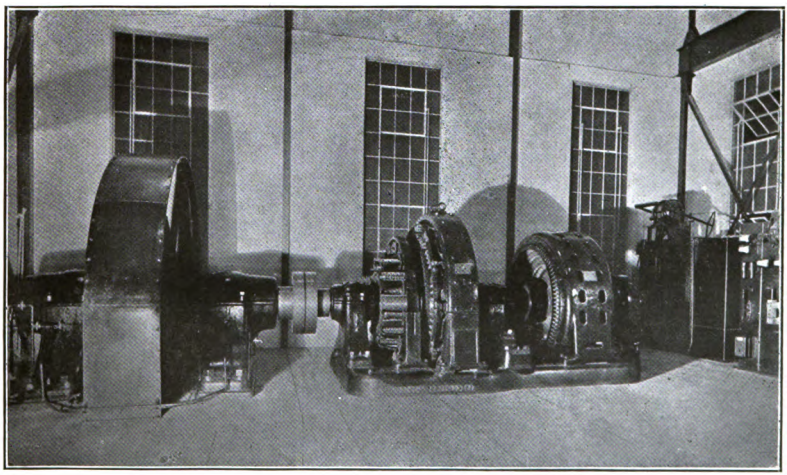


FIG. 2—VIEW OF FLYWHEEL MOTOR-GENERATOR SET [SAGE

Digitized by Google

Digitized by Google

Drums—cylindrical—double-clutched.
Diameter of drums..... 10 ft. (3 m.)
WR^2 of drums.....3,600,000 lbs. ft.²
Maximum hourly tonnage (2000 lbs.) 3500
ft. level..... 155
Assumed mechanical efficiency..... 85 per cent.

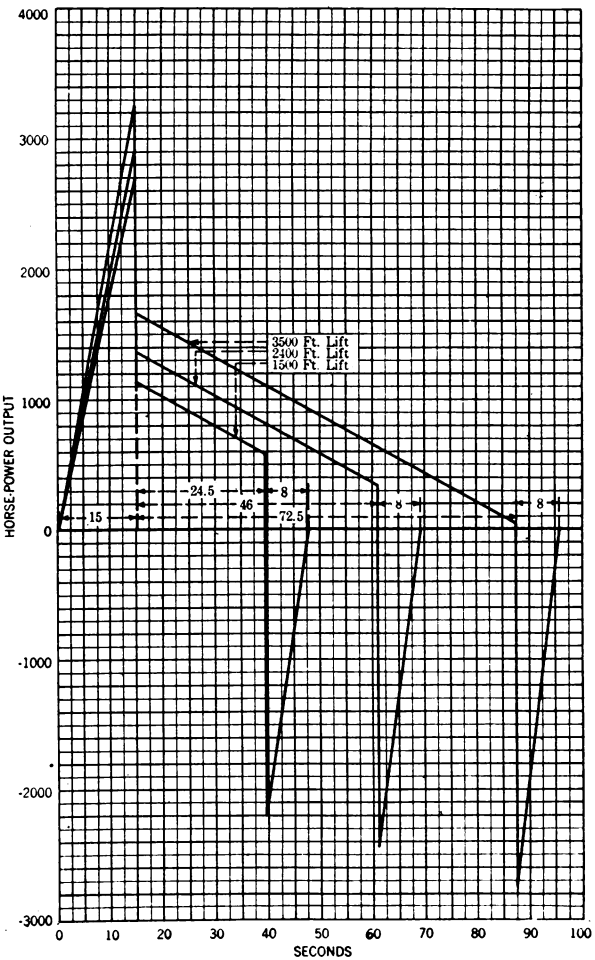


FIG. 3—CALCULATED HOIST DUTY CYCLES

The calculated cycles of duty for the various levels, upon which the capacity of the electrical equipment was based, are shown in Fig. 3. It is practically impossible to exactly predict the actual operating schedule in this class of service, but to insure continuity of service, the most important consideration

Digitized by Google

in installations of this kind, the first requisite is that the driving machinery have a safe margin of capacity. A heating guarantee of 40 deg. cent. rise for all parts of the electrical equipment was therefore made, for continuous operation, when hoisting the specified hourly tonnage from any level. The efficiency curves for the various machines are given in Fig. 4.

The estimated limits of demand from the power supply for the various levels were as follows:

1500 ft. level..... 650 kw.
2400 " " ..... 760 kw.
3500 " " ..... 865 kw.

	100%	75%	50%	25%	Per cent. of maximum hourly tonnage
1500 ft.....	267	200	133	67	Hourly tonnage
	2.46	2.58	2.83	3.57	Kw-hr. per ton
2400 ft.....	202	152	101	50.5	Hourly tonnage
	3.74	3.89	4.23	5.07	Kw-hr. per ton
3500 ft.....	155	116	77.5	38.7	Hourly tonnage
	5.54	5.75	6.17	7.45	Kw-hr. per ton

The estimated overall efficiencies corresponding to the maximum hourly tonnages are as follows:—

1500 ft. level—overall efficiency..... 46.2 per cent
2400 " " — " " ..... 48.3 per cent
3500 " " — " " ..... 47.7 per cent

The hoist is also used for practically all of the hoisting of an unproductive character, such as handling waste, men, timbers and supplies, and the hoisting of ore is done simultaneously with this sort of work.

The overall efficiency at which the ore is hoisted, that is, the ratio of the net work done in lifting a day's output of ore, to the kilowatt hours of electric energy used per day, is therefore much less than the figures given above. The mine is still in the development stage so that the unproductive work is a large proportion of the total required of the hoist.

At the present time the slip regulator is adjusted so as to

Digitized by Google

limit the demand to 400 kw., as this is sufficient for the present depths, and the present manner of hoisting.

Description

The hoist consists of two steel-plate drums 10 ft., in diameter, grooved to hold 1900 ft. (579.1 m.) of 1.5 in. (38.1 mm.) steel cable per layer. The drums are mounted between three bearings, on a single shaft which has an extreme length of 40 ft. (12.1 m.). Each drum is provided with an axial-plate-type clutch and a parallel-motion post brake. The diameter of the

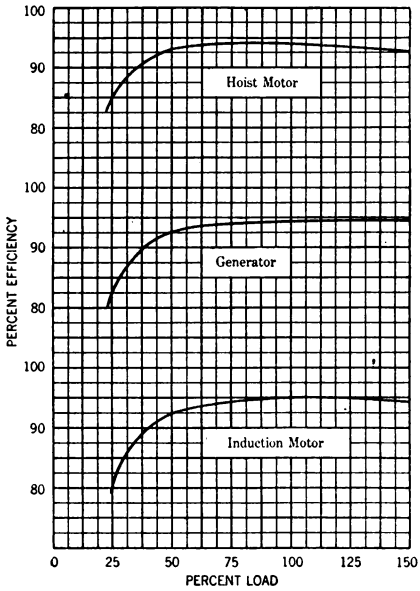


Fig. 4—Efficiency Curves

brake tread is 12 ft. (3.6 m.). The post brakes are made of structural shapes and steel plate to form a box girder. The brakes are released and the clutches operated by means of oil through cylinders with floating-level control, served by an oil accumulator in connection with a motor-driven triplex oil pump. A two horse power motor supplies all the power required for the brake and clutch engines. The weights by which the brakes are set are in the form of cylinders moving vertically in guides formed by part of the brake engine. In addition to the regulation dial-type depth indicators, the drum flanges are extended to provide a surface for spotting marks.

Digitized by Google

in installations of this kind, the first requisite is that the driving machinery have a safe margin of capacity. A heating guarantee of 40 deg. cent. rise for all parts of the electrical equipment was therefore made, for continuous operation, when hoisting the specified hourly tonnage from any level. The efficiency curves for the various machines are given in Fig. 4.

The estimated limits of demand from the power supply for the various levels were as follows:

1500 ft. level..... 650 kw.
2400 " " ..... 760 kw.
3500 " " ..... 865 kw.

	100%	75%	50%	25%	Per cent. of maximum hourly tonnage
1500 ft.....	267	200	133	67	Hourly tonnage
	2.46	2.58	2.83	3.57	Kw-hr. per ton
2400 ft.....	202	152	101	50.5	Hourly tonnage
	3.74	3.89	4.23	5.07	Kw-hr. per ton
3500 ft.....	155	116	77.5	38.7	Hourly tonnage
	5.54	5.75	6.17	7.45	Kw-hr. per ton

The estimated overall efficiencies corresponding to the maximum hourly tonnages are as follows:—

1500 ft. level—overall efficiency..... 46.2 per cent
2400 " " — " " ..... 48.3 per cent
3500 " " — " " ..... 47.7 per cent

The hoist is also used for practically all of the hoisting of an unproductive character, such as handling waste, men, timbers and supplies, and the hoisting of ore is done simultaneously with this sort of work.

The overall efficiency at which the ore is hoisted, that is, the ratio of the net work done in lifting a day's output of ore, to the kilowatt hours of electric energy used per day, is therefore much less than the figures given above. The mine is still in the development stage so that the unproductive work is a large proportion of the total required of the hoist.

At the present time the slip regulator is adjusted so as to

Digitized by Google

limit the demand to 400 kw., as this is sufficient for the present depths, and the present manner of hoisting.

Description

The hoist consists of two steel-plate drums 10 ft., in diameter, grooved to hold 1900 ft. (579.1 m.) of 1.5 in. (38.1 mm.) steel cable per layer. The drums are mounted between three bearings, on a single shaft which has an extreme length of 40 ft. (12.1 m.). Each drum is provided with an axial-plate-type clutch and a parallel-motion post brake. The diameter of the

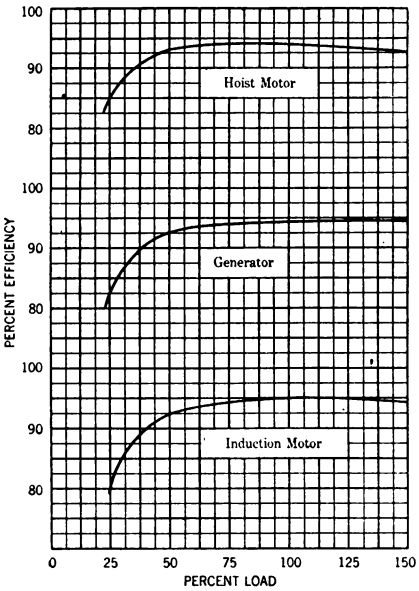


Fig. 4—Efficiency Curves

brake tread is 12 ft. (3.6 m.). The post brakes are made of structural shapes and steel plate to form a box girder. The brakes are released and the clutches operated by means of oil through cylinders with floating-level control, served by an oil accumulator in connection with a motor-driven triplex oil pump. A two horse power motor supplies all the power required for the brake and clutch engines. The weights by which the brakes are set are in the form of cylinders moving vertically in guides formed by part of the brake engine. In addition to the regulation dial-type depth indicators, the drum flanges are extended to provide a surface for spotting marks.

Digitized by Google

The bearings are all of the two-part type, provided with gravity feed lubrication, in addition to oil rings. Sight-feed oil guages are provided for all the bearings.

To the drum shaft is coupled an 1800-h.p., 80-rev. per min., 525-volt, d-c. motor, front and side elevations of which are shown in Fig. 5. The motor is supplied with two bearings, and sole plates; the armature shaft is 14 in. (36 cm.) in diameter in bearing by 11 ft. 5 in. (3.4 m.) long, and has a forged half-coupling for connection to a corresponding half-coupling on the drum shaft. The armature is 9.5 ft (2.8 m.) in diameter, while the outside diameter of the magnet frame is 14 ft. 5 in. (4.3 m.). The motor has 16 main field poles, the coils being wound for 125-volt excitation, and has commutating poles to insure good commutation

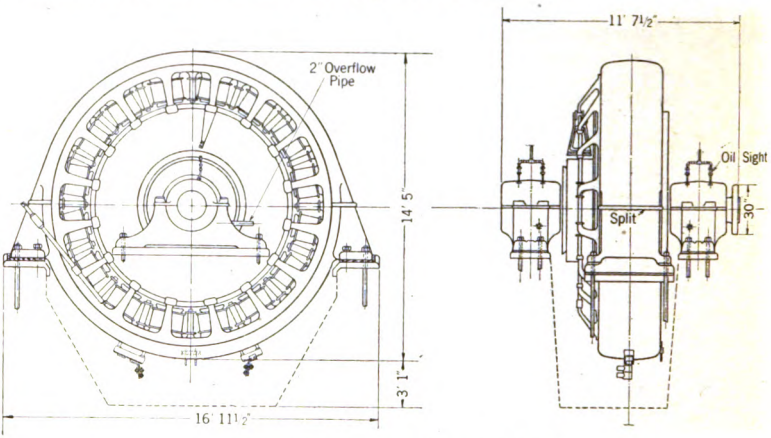


FIG. 5—OUTLINE OF HOIST MOTOR

at the heavy overloads encountered in the service. The bearings in addition to being ring oiled, receive lubrication from the gravity feed oiling system. The extreme length of the hoist, with motor, is 51 ft. 9 in. (15.7 m.)

The motor receives its power through a set, consisting of a generator driven by an induction motor, and a direct-coupled flywheel and exciter, shown in outline in Fig. 6.

The generator has a continuous capacity of 1300 kw., at 525 volts, and in order to successfully commutate the heavy currents at the low voltages, it is equipped with commutating poles, and, in addition, a compensating winding is placed in the pole faces of each of the 12 main poles. As in the case of the hoist motor, the main-field excitation is at 125 volts.

Digitized by Google

The induction motor is rated 1150 h.p., 3 phase, 60 cycles, 2200 volts, and has a synchronous speed of 514 rev. per min. It is of the wound-rotor type, with collectors for connection to the automatic slip regulator.

The flywheel is built up of thick rolled steel plates, 11 ft. 10 in. (3.6 m.) in diameter, so that the peripheral speed at synchronism is 19,100 feet (5.8 km.) per minute. The width of

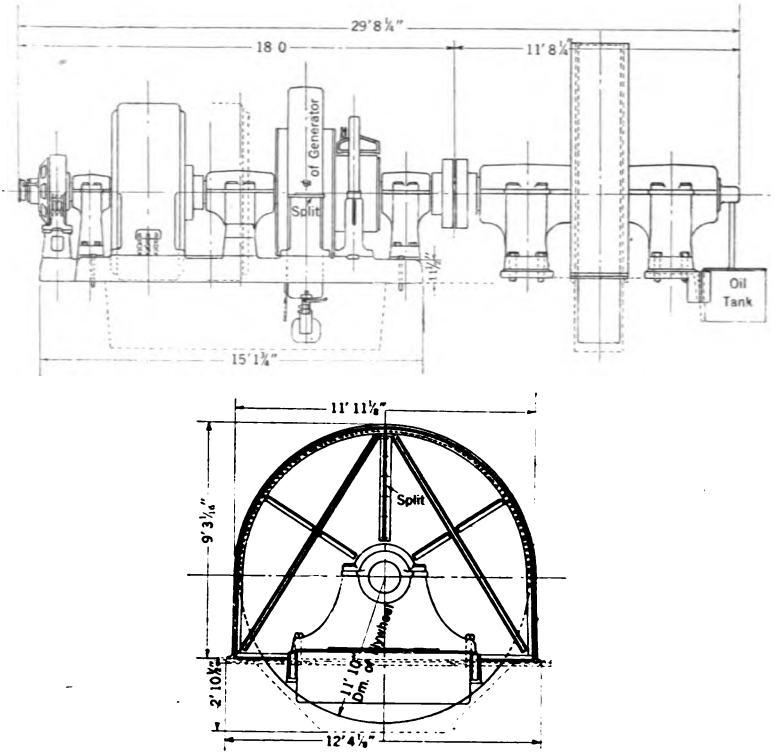


FIG. 6—OUTLINE OF MOTOR-GENERATOR SET

face is 20.5 in. (52 cm.) making the total weight 92,000 lbs. (41,730 kg.), exclusive of shaft. The plates are securely riveted together by steel rivets. The wheel is mounted between two bearings, and coupled to the generator by a Francke-type flexible coupling. A special grade of hard babbitt is used in the supporting bearings. Lubrication is afforded both by means of a low-pressure oil pump geared to the shaft supplemented by ring oiling. The geared pump begins to supply the bearings with oil practically

Digitized by Google

as soon as the wheel turns over. The oil reservoir is sunk below the floor line at the end of the flywheel bearing, and contains coils for the circulation of cooling water.

In order to reduce the demand on the power system, when starting the set, a small motor-driven, high-pressure oil pump is provided to supply oil pressure under the bearings, this pump being put into operation only when required for this purpose. With this starting pump in operation, the set and wheel started from rest with 80 per cent of full-load current from the power system.

A close fitting steel plate cover is provided for the wheel above the floor line, the pit in the foundation virtually forming the lower portion of the enclosing casing.

The exciter armature is mounted on an extension of the induction motor shaft, the field frame being bolted to an extension of the base. The exciter has a continuous rating of 21 kw., at 125 volts.

A cast iron base is provided under the induction motor and generator and sole plates under the flywheel bearings. The foundation under the various units is of re-inforced concrete extending down to the bed rock, insuring stability of alignment.

Control

The hoist-motor speed and direction of rotation are controlled by varying the strength and reversing the polarity of the generator field. The field rheostat is provided with a large number of points giving a corresponding large number of speeds in both directions. Between the motor and generator there is inserted an overload circuit breaker and a single-pole line switch.

In the design and installation of the entire equipment, careful consideration was given to the matter of safety of operation, with the result that the effects due to carelessness on the part of the operators are obviated and protection to the men and apparatus is provided in almost every emergency.

The arrangement of the control levers is extremely simple, there being but one power lever, a forward movement corresponding to one direction of rotation and a backward movement, the reverse. This lever with the two brake levers, one on either side, completes the lever group. The clutches are operated by a throw, either in or out, of a crank through an arc of 180 deg.

A center-zero d-c. ammeter and voltmeter are mounted in the line of vision with the depth indicators.

Digitized by Google

A Welch safety device compels slowing down at the proper rate and provides protection against overwinding and overspeeding. As an additional protection, limit switches actuated by the skips themselves are installed in the guides. These switches, as well as the Welch device, cause the d-c. circuit breaker to open, in addition to setting the hoist brakes. In general, any emergency which will cause the d-c. circuit breaker to open will cause the brakes to be applied. The d-c. circuit breaker will open under any of the following emergencies:

(a) Extreme d-c. overload
(b) Overwind top or bottom
(c) Loss of exciter voltage
(d) Loss of motor-field excitation
(e) Overspeed of hoist
(f) Overspeed of motor-generator set.

The opening of the main line a-c. oil circuit breaker will not open the d-c. circuit breaker, nor set the hoist brakes, but the operator is free to continue hoisting as long as the stored energy in the flywheel will permit. The opening of the line switch is indicated in the usual manner by the ringing of a bell. When the d-c. circuit breaker has been opened under any of the above mentioned emergencies, and an application of the brakes made, the brakes cannot be released until the controller lever has first been returned to the central position.

After an overwind has occurred, it is necessary for the hoist operator to throw a small switch before power can again be applied to the motor and motion is possible only in the lowering direction.

The total energy in the flywheel at 94 per cent synchronous speed is 117,000 h.p-sec. of which approximately 50 per cent is available for operating the hoist in the event the set was disconnected from the power supply, the limitation being the speed at which the d-c. exciter is no longer able to hold up its voltage. If required, a complete trip with a fully loaded skip could be made from a depth of 1500 ft. (457.2 m.) on the energy of the flywheel, and a load of men could be hoisted from the deepest level.

Hoisting "out of balance" can be carried on without causing excessive speed reduction of the set nor necessitating a higher limit of demand from the power supply.

The liquid slip regulator used with this equipment is worthy of special mention, as being a decided departure in important

Digitized by Google

details from the heretofore generally accepted design. In the latter, it was necessary to make a water-tight joint between the tile or porcelain vessels, and the cooling tank, and also between the tile and the electrodes, clamping rings or draw volts being used for this purpose. In many instances, this construction in connection with temperature changes resulted in broken tiles, causing much annoyance.

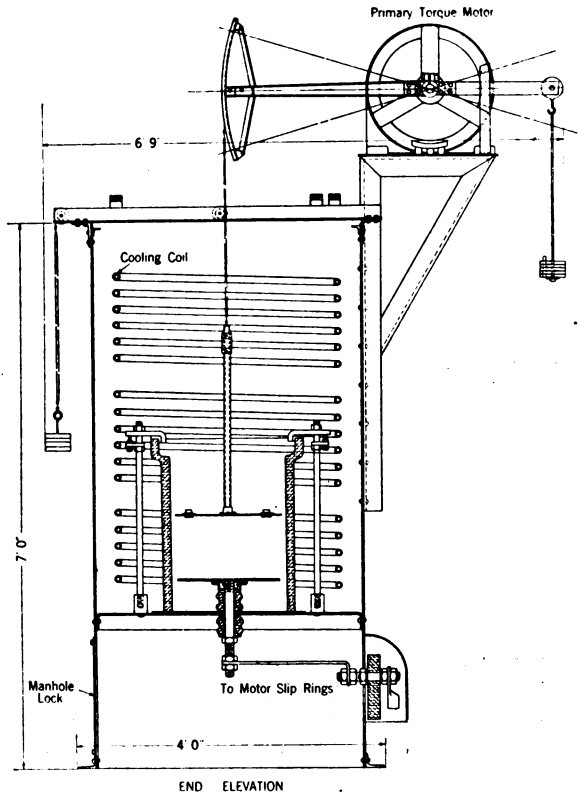


FIG. 7—AUTOMATIC SLIP REGULATOR—CROSS SECTION

In the present design, a sectional end view of which is shown in Fig. 7, the tiles are simply placed upon a rubber mat on the steel bottom of the tank, the only water-tight joint being that between the lower electrodes and the bottom of the tank. Only enough pressure is applied on the tile by the holding down bolts to hold it in place, the purpose of the tiles being merely to serve as barriers to prevent leakage between phases. Common sewer

Digitized by Google

tiles are used for the purpose. The value of the input limit is adjusted in the usual manner by varying the number of the counterbalancing weights.

Tests

The first set of tests was for the purpose of analyzing a typical day's run under ordinary conditions, as regards its relation to the electrical equipment.

In the second test, measurements were made of the electrical quantities for a few trips, to determine, if possible, the efficiency while hoisting under known conditions.

In conducting the tests, the following measuring instruments were used:

Curve-drawing a-c. wattmeter—30 in. feed per hour.
Graphic recording a-c. ammeter.
" " d-c. ammeter.
Indicating liquid column tachometer.
Graphic recording d-c. voltmeter.
Karlic tachograph.
Indicating a-c. wattmeter.
" a-c. voltmeter.
" a-c. ammeter.
Integrating polyphase watthour meter.

First Test. A log was kept of all the movements of the hoist from 7:00 a.m. to 7:00 p.m., recording the time, the nature of all trips, quantity of ore, etc. The only instruments in use were the a-c. recording watmeter—30 inches feed per hour, Karlic tachograph and integrating watthour meter.

As mentioned in the preceding paragraphs, there are no special designated periods of the day during which the hoist is used exclusively for the hoisting of ore, but this is carried on simultaneously with the unproductive work, as the conveying of timber, men and supplies. Moreover, the hoisting is of such an intermittent nature, that a straight line input to the motor-generator set is not even approximated, even at the low limit of 400 kw. Storage or bins are under construction, but were not in operation at the time of the tests. To illustrate the character of the load, a portion of a typical day's load chart is shown in Fig. 8. This curve is reproduced from one of the daily records from the 30 in. per hour curve-drawing wattmeter included with the switchboard equipment.

Digitized by Google

The results of this test are given below.

Duration of test	12 hours.
Actual time hoist in motion	3.5 hours.
Total number of trips made	280
Number of skips of ore hoisted	63
Percentage ore trips of total	22.5 per cent.
Total weight of ore hoisted	252.5 tons
Average weight of ore per skip	4.01 tons
Average lift of ore	1428 ft. (435.2 m.)
Net work done on ore-total	272 kw-hr.
" " " " " per trip	4.32 kw-hr.
" " " " " " ton	1.08 " "
Kw-hr. energy used during day	1500 kw-hr.
Total kw-hr. energy used, including non-productive work per ton ore hoisted	5.94 kw-hr.

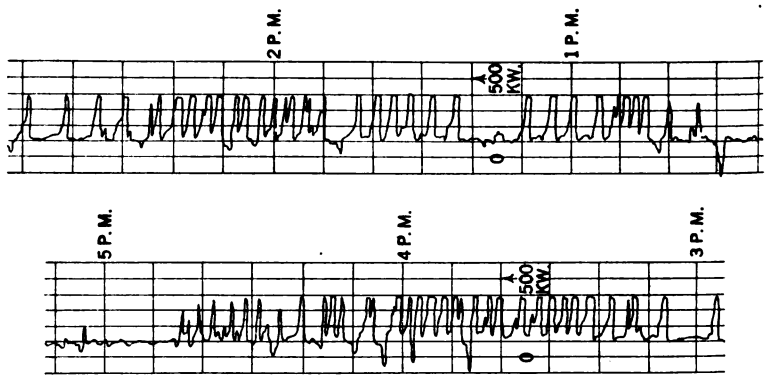


FIG. 8—LOAD DIAGRAM OF A-C. INPUT

Kw-hr. used while hoist at rest	680 kw-hr.
" " " " hoisting ore	582 " "
" " returned to power system	14.6 kw-hr.
Overall efficiency while hoisting ore	46.7 per cent.

The trips with ore were divided among the levels as follows:

Level	No. Trips	Actual Lift
1000 ft. (304.8 m.)	6	1068.5 ft. (325.6 m.)
1100 "	3	1170.0 "
1200 "	3	1271.2 "
1300 "	20	1372.5 "
1400 "	7	1473.5 "
1500 "	22	1574.5 "
1800 " (548.6 m.)	2	1915.2 (583.7 m.)

The weight of ore hoisted was obtained by observing the number of cars dumped into each skip and using an average weight per car obtained from a large number of cars.

Digitized by Google

The calculated net work done in lifting the ore is subject ot some error, inasmuch as during about 25 per cent of the trips timber or men were lowered in counterbalance with the ore. On the other hand, men were hoisted with the ore during about 20 per cent of the trips.

During about 50 per cent of the trips with ore, at least one stop was made between the loading level and the dump, there being a maximum number of six such stops. The total kilowatt hours used was obtained from readings taken on the watthour meter at the beginning and end of the test.

The energy used during the ore trips was obtained from the record made by the 30 in. per hour curve-drawing wattmeter with the aid of a rolling planimeter. The energy returned to the system was obtained in the same manner.

The time during which the hoist stood at rest was taken from the tachograph record.

Second Test. In order to secure as rapid hoisting as possible, there was accumulated at the 1500 foot level, 30 cars of ore making possible 5 consecutive trips, as fast as the skips could be loaded.

Continuous records were made on the graphic meters of the d-c. voltage and current and of the a-c. current. A time marker marked every second on all of the records, simultaneously. The speed of the motor-generator set was read at frequent intervals and telegraphed to one of the graphic records at the instant of reading, a record of the consecutive readings being kept which was later transferred to the graphic record. The speed of the hoist motor was taken from the tachograph record and the 30 in. per hour recording wattmeter supplied a record of the power delivered to the motor-generator set.

Fig. 9 is a consolidation of all of the records and readings taken for the five consecutive trips.

By combining the two d-c. graphic records, the d-c. power curves were obtained.

The following conditions pertain to this test:

Hoisting done in balance	
Duration of test	565 seconds
Lift	1574.5 ft. (479.9 m.).
Number of skips hoisted	5
Weight of ore hoisted	20.3 tons
Average weight per skip	4.06 tons
Net work done—total	24.1 hr.
Average time per trip	113 sec.

Digitized by Google

Actual running time total	310 "
" " " av. per trip	62 "
Time at rest-total	255 "
" " " average per trip	51 "
Average time for acceleration	22 "
Average time for running at full speed	15.5 "
Average time for retardation	24.5 "
Average rope speed	1525 ft. per min.
Max. " "	2580 " " "
Average speed of M-G. set	486 " " "
Hoist motor input (exclusive shunt field)	32.64 kw-hr.
" " output	28.2 " "
Mechanical efficiency of hoist	83 per cent.
Energy input to M-G. set total	50.5 kw-hr.
Kw-hr. per ton	2.49
Overall efficiency	4.77

The energy dissipated in the various parts of the equipment was found to be as given in the table below.

	Kw-hr.	Per cent. of net work
Losses in mechanical parts of hoist, sheaves, guides, etc.	4.1	17.0
Hoist motor losses	6.25	25.9
Generator losses	5.53	22.9
Induction motor losses	3.99	16.6
Flywheel losses	4.08	17.0
Slip regulator losses	2.12	8.8
Exciter losses	0.39	1.6
Total losses	26.46	109.8 per cent.
Net work done on ore	24.1	
Total energy consumed	50.56 kw-hr.	
Overall efficiency	47.66 per cent.	

The hoist motor input was measured directly, and the output was obtained by deducting the losses which were based on factory test-results.

The power input to the motor-generator set when running light as measured by the 30 in. per hour curve-drawing wattmeter, and checked by the indicating wattmeter was 80 kw. at 512 rev. per min. For the average speed of the set during the test this was taken at 78 kw.

The segregation of the losses in the set was made from results of tests made in the factory. The running light input to the set includes:

Flywheel bearing friction and windage
Generator " " " "
Ind. motor " " " "
" " core loss and running light copper loss.
Hoist motor shunt field (with economy resistance in series)
Exciter loss with load of motor field.

Digitized by Google

The same total loss in the equipment is obtained by adding to the running-light loss of the set, the increase in losses while under load, these being readily calculated. On this basis, the result is as follows:

Motor shunt field (increase)	0.248	kw-hr.
Ind. motor copper loss (increase)	0.223	" "
Exciter loss (increase)	0.060	" "
Generator losses (excl. fric. & w'd'ge)	3.019	" "
Motor losses (excl. shunt field)	4.440	" "
Regulator losses	2.120	" "
Running light loss of set	12.250	" "
Friction in mech. parts of hoist	4.1	" "
Total	26.460	

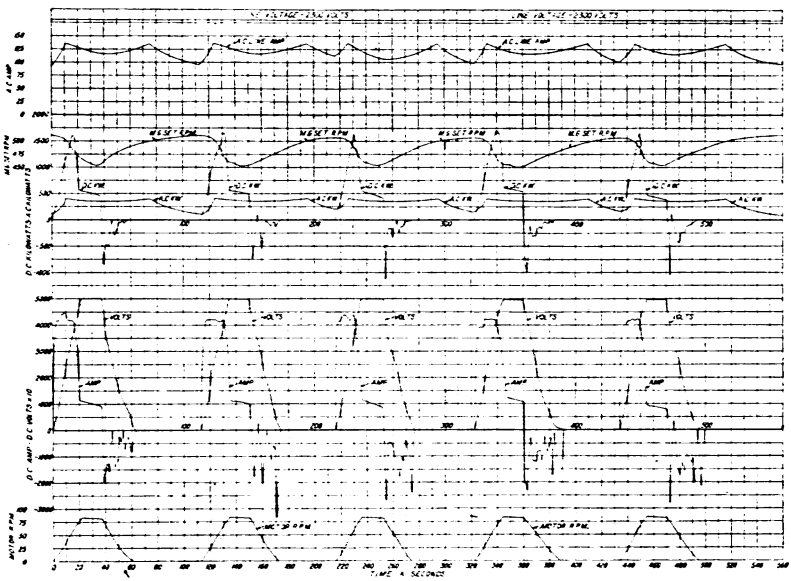


FIG. 9—CONSOLIDATED CURVES FROM TESTS

An item not included in the above segregation consisting of approximately 0.25 kw-hr., used in operating the accumulator oil pump and the brake solenoids is also included in the running light input.

The total energy accounted for is therefore 50.81 kw-hr., as against 50.5 shown by the wattmeter.

The energy output of the generator, as obtained from the d-c. power curves by the aid of a rolling planimeter was 32.64 kw-hr., and the input 38.17 kw-hr. The input to the generator was at the rate of 243 kw., so that during the trips, approxi-

Digitized by Google

mately 27.5 kw-hr., were required from the flywheel. The average speed reduction of the set during hoisting was 10.6 per cent on the basis of which, the energy given up during the five cycles was 96,500 kw-sec. or 26.8 kw-hr., which checks fairly well with the figure given above.

In general, the test results check very well with the estimated performance. The friction losses in the hoist, sheaves, rope and guides proved unexpectedly low, but the shaft guides are in very good repair, and the cage rides almost as smoothly as a passenger elevator. Also, the hoist drums run true and with no interference with the brake shoe blocks; the head sheaves and idlers are well lubricated and easy running.

The efficiency of hoisting exceeded that anticipated, even with the light loads, the load per skip being but 80 per cent of that considered normal. With heavier loads, as when hoisting high grade copper ore, the efficiency would be further increased. Hoisting was done at slightly less than 50 per cent of the maximum rate for this level and the power consumption was 2.49 kw-hr. per ton as compared with 2.83 kw-hr., expected.

The tendency should be for the efficiency to increase at the greater depths, the maximum probably being reached at the intermediate levels.

The time for retardation is considerably longer than that used in calculating the duty cycles, and is the result of the rather close setting of the Welch safety device. At present there is no particular reason for rapid hoisting, and the management being inclined to a policy of safety, require the slower rate of retardation. A reduction in the retardation period would further tend to a betterment of the efficiency of hoisting.

The standby losses are considered particularly low, for an equipment of this capacity.

It is believed that by increasing the loading time so as to obtain a more uniform input to the power set, decreasing the retardation period and bringing the load up to normal, the hoisting efficiency of this outfit will reach 50 per cent at this level.

It is believed that the results of these tests give fairly accurate information as to the operating characteristics of the hoist at Elm Orlu, and indicate, in general, the results to be expected of the performance of other Ilgner equipments in similar service.

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON TRANSMISSION AND DISTRIBUTION

To the Board of Directors,

The Committee on Transmission and Distribution submits the following report for the year of 1916-17:

In order to find a starting point for the work of this committee a letter was addressed to each of its twenty-three members asking for definite suggestions as to the most urgent problems concerning transmission and distribution. Replies were received from thirteen individuals containing twenty-four suggestions. Twelve of these suggestions related to high-tension insulators, seven to underground cables, one to lightning protection, one to relays, one to towers, one to reactances, and one to suppression of transient voltages. It appeared from the result of this inquiry that troubles with high-tension insulators and underground cables were uppermost in the minds of those who replied, most of whom were either operating men or men in close touch with the operation of transmission and distribution systems.

After conference with a few of the members of the committee, it was decided to confine the work of this year to the subjects of high-tension insulators and underground cables. It was further decided that on account of the urgency of the problems involved, particularly regarding high-tension insulators, that the subjects be treated so far as possible from the practical standpoint, theoretical discussions being eliminated except so far as they indicated definite practical results.

High-Tension Insulators

During the last few years the troubles with high-tension insulators have become cumulative. During the summer seasons of 1915 and 1916 the failure of insulators on some long distance transmission lines resulted so disastrously in the way of interruptions that it was evident something had to be done unless we were content to relegate long distance service to the category of intermittent or second class power. Particularly on the Pacific coast these troubles had become acute. Some of our best engineers were already working on the problem. A number of the

Digitized by Google

far western companies had clubbed together and employed the best talent they could find to carry on the investigation. Professor Ryan of Leland Stanford, Jr. University is now busy carrying out experiments on a very large scale to determine the effects of porosity in porcelain. All who are acquainted with Professor Ryan and his work know that his results when published will carry authority on this point. It was a great disappointment to us that the paper promised by Professor Ryan on the results of his investigation, to be presented at this meeting, had to be deferred a few months on account of extraordinary weather conditions, making it impossible to complete the data.

Professor Peaslee of the Oregon Agriculture College has attacked the problem from the chemical and microscopical point of view while others have been investigating the effects of expansion and contraction of insulators on dielectric strength. The manufacturers of insulators have also been busy. This is shown in Mr. Austin's paper presented at this meeting. The manufacture of high-tension insulators from fused quartz is recommended by Mr. Peaslee. It is hoped that some one properly equipped will pursue this line of investigation.

What has been accomplished? The last word has not been said on any of these lines of investigation and will not be said for a long time. So far as porcelain insulators are concerned we know (1) that porosity must be reduced to the lowest practical limit to prevent absorption, (2) that joints must be so designed and made that the insulators will not crack from expansion and contraction effects, (3) That insulators must have ample margin of mechanical strength.

Underground Cables

It is only within the last few years that users of underground cables have begun to realize the importance of disposing of heat due to copper and other losses. Conduit lines were designed 15 or more years ago with the idea that there would be from three to five watts lost per foot of cable. Even engineers seemed to have a sort of blind faith that these watts would get away somewhere, somehow. No one ever stopped to consider what would happen in case these watts did not get away. However, we have found out in the school of experience. The lesson has been costly, but it has been learned. It is scarcely exaggeration to say that as much skill is required to design a conduit line as to design a dynamo.

Digitized by Google

The problem is to dispose of heat. This may be done in two ways: (1) by minimizing the amount produced, (2) by quickly conducting away the heat that is produced. The first is largely the problem of the cable manufacturer. We have two papers this year which show great advance in our knowledge of dielectric losses. The use of certain insulating materials in saturating paper insulation greatly reduces these losses. This is well brought out in the papers by Messrs. Bang and Louis, and by Messrs. Clark & Shanklin. The reduction in losses is not a small amount requiring laboratory tests to find. Cable ratings under some conditions may be more than doubled. These investigations are highly profitable and should be continued. The second point relating to conducting the heat away from cables after it has been generated has been brought out by Mr. Harper. No operating engineer can read this paper without a deep and sympathetic feeling of comradeship with the author. Most of the underground conduits now in use were built without any regard to their capacity to dissipate heat and thereby immense sums of money have been thrown away.

Mr. Roper's paper on high-tension cable joints is the very highest authority on this subject and is worth careful study. Probably there are more breakdowns at the present time in joints than in all the rest of a cable system. Practically all of these breakdowns are avoidable by carefully following the recommendations laid down by Mr. Roper.

Suggestions for the Future

For the future activities of this committee, I suggest that it pursue the high-tension insulator problem. The work has been started, but there is much to be done. Investigations so far indicate pretty clearly where the weaknesses lie and this is but one step from the solution of the problem. We suggest that further investigations be made on the subject of dielectric loss in cables to the end that the laws governing it may be definitely known. It will then be possible for the manufacturer to give an even quality of cable with minimum dielectric loss.

We further suggest that the use of 20,000- or 30,000-volt cables be investigated. Some 20,000-volt cable is now in use in this vicinity, but we greatly desire to hear all about it.

L. E. Imlay, *Chairman.*

Digitized by Google

ANNUAL REPORT OF TRACTION AND TRANSPORTATION COMMITTEE

To the Board of Directors,

The Traction and Transportation Committee submits the following report for the year 1916-17:

At the beginning of this year, the scope of the Traction and Transportation Committee, which superseded the Railway Committee in accordance with the recommendations of the Special Committee on Re-organization of Technical Committees, was considerably enlarged, and in order properly to cover the field, more members were added. The main committee was divided into five sub-committees, as follows:

Urban and Interurban Railways: H. H. Adams, Chairman, L. P. Crecelius, W. J. Harvie, E. D. Priest, C. Renshaw.

Trunk Lines and Heavy Traction: N. W. Storer, Acting Chairman, A. H. Babcock, George Gibbs, Hugh Hazelton, E. B. Katte, John Murphy, W. B. Potter, Wm. McClellan.

Electrification Data: E. B. Katte, Chairman, R. Beeuwkes, J. V. B. Duer, C. H. Quinn.

Interference of Electric Railway Circuits With Telephone and Telegraph Lines: C. F. Scott, Chairman, A. H. Babcock, J. B. Taylor, H. S. Warren.

Effects of Grounded Railway Circuits on Pipes and Underground Structures: E. J. Blair, Chairman, J. V. B. Duer, John Murphy, A. S. Richey, H. S. Warren.

Through the Sub-Committee on Urban and Interurban Railways, it is hoped to bring the Institute into closer touch with the great body of electric railway men who now derive most of their support and assistance from the A. E. R. A. One paper on "Gear Losses" has been secured by this committee, and others on "Railway Motor Ventilation" are in preparation.

One paper bearing specially on the question of "Heavy Traction" has been presented during the year. This was the paper by Mr. R. E. Hellmund, on the subject of "Regenerative Braking of Electric Vehicles," which was presented at the Pittsburgh meeting of the Institute in January. The paper itself is a very complete treatise on the subject covering the problems and the various solutions involved in regenerative braking with

Digitized by Google

different systems of electrification. It forms an excellent basis for discussion.

The paper and the discussion that followed showed plainly the great progress that has been made in the practical application of regenerative braking on heavy traction lines in this country. The advantages of the constant-speed type of locomotive with the induction motor in use on the Norfolk and Western Railway were clearly set forth; also the advantages of the variable-speed type of locomotive in use on the Chicago, Milwaukee and St. Paul and the Lake Erie and Northern locomotives where direct current is used, were fully brought out. The important fact to be derived from the discussion is that regenerative braking is an accomplished fact and must always be considered in any electrification scheme where heavy-grade work is involved. It has been demonstrated beyond question that it is a much more reliable and safe method of holding trains on descending grades than the use of air brakes alone since, in any case, where regenerative braking is used, the air brake is always available to stop the trains in emergencies.

While regenerative braking has not been applied to trains of multiple-unit cars, or to single cars, in this country, on a commercial scale, the hope and belief were expressed that successful application of regenerative braking on both would be only a question of a short time. The application in such work will be due, not to the safety and reliability of operation, as in the heavy grade work, so much as to the economies which can be effected in power consumption. It is conservatively estimated that not less than 20 per cent of the power now consumed in the ordinary multiple-unit trains in city and suburban service, can be saved by the application of regenerative braking. This will involve increased capacity in the driving motors and a small amount of additional control equipment, but the net saving will far outweigh the additional cost of equipment and maintenance.

The effort of the Sub-Committee on Electrification Data to collect information from existing railways, met with the usual obstacles. It was decided that any costs which might be figured on the electrifications now in operation would be of very little value to the Institute, since the conditions under which the installations were made varied so widely, and unless all of the facts could be known the figures would be very misleading.

The Sub-Committee on Interference of Electric Railway Circuits with Telephone and Telegraph Lines did a considerable

Digitized by Google

amount of work, but it was not deemed advisable to make the results public at this time.

The Sub-Committee on the Effects of Grounded Railway Circuits took up the question with the National Committee on Electrolysis, with the special object of seeing that the effects of the high-voltage direct-current lines where the drop in the return circuit necessarily reaches comparatively high figures, was thoroughly considered.

For the coming year, it is recommended that the committee continue the work which has been undertaken this year. While any papers which would raise the question of system of electrification are distinctly undesirable, it is recommended that a series of short papers by representative steam railway men be secured, which would explain in considerable detail the problem which must be met by the electric railway engineers in superseding the steam locomotive on the heavy transportation lines. This should include not only the problem as it confronts us today, but what the future has in store for us as far as these railway men can predict. There is a constant tendency towards the use of much heavier and longer trains, larger locomotives and higher speeds, both in freight and passenger service. We need further information as to what the limits are likely to be; how much power must be concentrated in one train; how necessary it is to operate the trains under close headway during emergency conditions; how much it is worth to the railways to be able to do this; what are the physical limitations that will be involved, etc., etc.

The present committee is larger than can be used satisfactorily and it should be reduced to one-half or two-thirds the present number, and composed of men who are able and willing to devote their time to the consideration of problems of electric railroads.

N. W. STORER, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON ELECTROPHYSICS

To the Board of Directors:

The Committee on Electrophysics submits the following report for the year 1916-17:

Very rapid advances are being made in physics; entirely new fields are being opened up, new conceptions formed. In order that engineering may advance as rapidly as it should, it is necessary for the engineer to keep familiar with and to apply the discoveries of the scientist and the physicist. Much of the work of the physicist is published in various scientific and philosophical magazines seldom read by engineers. It is difficult for the engineer to get the perspective view which he needs and should have. Realizing this, the Electrophysics Committee were able to secure Dr. R. A. Millikan, President of the American Physical Society, to deliver a lecture on "Modern Physics" at the mid-winter convention in New York, on the evening of February 15th. The enthusiasm with which this lecture was received by an overflowing audience is without precedent. Dr. Millikan's lecture will be published in the TRANSACTIONS. We believe at least one such lecture should be delivered annually.

Cooperation and mutual understanding between physicists and engineers are of the utmost importance. The Technical committee of the Physical Society bears a somewhat similar relation to its society with respect to engineering as our committee does to our society with respect to physics. We have had the most helpful cooperation from this committee and much of the success of our Electrophysics session at the mid-winter convention on February 15th was due to their active assistance. The members of the Physical Society were invited to our meeting and took part in our discussions as well as attending Dr. Millikan's lecture. Their technical committee also arranged for meetings of the Physical Society in New York immediately following our meeting, which many of our members attended. We believe that joint or parallel meetings are of great value. It would be desirable, if practicable, to have interlocking members on the committees. For instance the chairman of one committee an ex-officio member of the other committee. In

Digitized by Google

amount of work, but it was not deemed advisable to make the results public at this time.

The Sub-Committee on the Effects of Grounded Railway Circuits took up the question with the National Committee on Electrolysis, with the special object of seeing that the effects of the high-voltage direct-current lines where the drop in the return circuit necessarily reaches comparatively high figures, was thoroughly considered.

For the coming year, it is recommended that the committee continue the work which has been undertaken this year. While any papers which would raise the question of system of electrification are distinctly undesirable, it is recommended that a series of short papers by representative steam railway men be secured, which would explain in considerable detail the problem which must be met by the electric railway engineers in superseding the steam locomotive on the heavy transportation lines. This should include not only the problem as it confronts us today, but what the future has in store for us as far as these railway men can predict. There is a constant tendency towards the use of much heavier and longer trains, larger locomotives and higher speeds, both in freight and passenger service. We need further information as to what the limits are likely to be; how much power must be concentrated in one train; how necessary it is to operate the trains under close headway during emergency conditions; how much it is worth to the railways to be able to do this; what are the physical limitations that will be involved, etc., etc.

The present committee is larger than can be used satisfactorily and it should be reduced to one-half or two-thirds the present number, and composed of men who are able and willing to devote their time to the consideration of problems of electric railroads.

N. W. STORER, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON ELECTROPHYSICS

To the Board of Directors:

The Committee on Electrophysics submits the following report for the year 1916-17:

Very rapid advances are being made in physics; entirely new fields are being opened up, new conceptions formed. In order that engineering may advance as rapidly as it should, it is necessary for the engineer to keep familiar with and to apply the discoveries of the scientist and the physicist. Much of the work of the physicist is published in various scientific and philosophical magazines seldom read by engineers. It is difficult for the engineer to get the perspective view which he needs and should have. Realizing this, the Electrophysics Committee were able to secure Dr. R. A. Millikan, President of the American Physical Society, to deliver a lecture on "Modern Physics" at the mid-winter convention in New York, on the evening of February 15th. The enthusiasm with which this lecture was received by an overflowing audience is without precedent. Dr. Millikan's lecture will be published in the TRANSACTIONS. We believe at least one such lecture should be delivered annually.

Cooperation and mutual understanding between physicists and engineers are of the utmost importance. The Technical committee of the Physical Society bears a somewhat similar relation to its society with respect to engineering as our committee does to our society with respect to physics. We have had the most helpful cooperation from this committee and much of the success of our Electrophysics session at the mid-winter convention on February 15th was due to their active assistance. The members of the Physical Society were invited to our meeting and took part in our discussions as well as attending Dr. Millikan's lecture. Their technical committee also arranged for meetings of the Physical Society in New York immediately following our meeting, which many of our members attended. We believe that joint or parallel meetings are of great value. It would be desirable, if practicable, to have interlocking members on the committees. For instance the chairman of one committee an ex-officio member of the other committee. In

Digitized by Google

addition, to Dr. Millikan's lecture the following important scientific papers were read:

"Corona and Rectification in Hydrogen", by J. W. Davis and C. S. Breese.

"The Electric Strength of Air-VII", by J. B. Whitehead and W. S. Brown.

"Oscillating-Current Circuits by the Method of Generalized Angular Velocities", by V. Bush.

Many important physical papers of great value and many scientific discoveries made by engineers, which naturally first appear in engineering journals, are lost to physicists because physicists do not read these journals and because when they are reviewed and reported they are recorded under the heading of "Engineering" rather than under the heading of "Physics". This is a great economic loss, and attempts should be made to remedy this condition.

We believe efforts should be made to continue and to further cooperation between engineers and physicists; it is to their mutual advantage.

F. W. PEEK, JR., *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON LIGHTING AND ILLUMINATION

To the Board of Directors,

The Committee on Lighting and Illumination submits the following report for the year 1916-17:

The Lighting and Illumination Committee sought, early in the year, to find some specific activity upon which it might legitimately concentrate its efforts with profit to the members of the Institute and with some measure of good to the art of lighting. This ambition was not realized, as the committee was unsuccessful in finding such an activity that was not already under consideration or that ought not more logically be undertaken by the Illuminating Engineering Society, which is specially organized for the investigation of lighting problems in general.

The Lighting and Illumination Committee considers that it may render a valuable service to the Institute by securing papers on illumination topics that are of peculiar interest to the members of the Institute or are of such general interest as to warrant their presentation in abstract form before this body. The committee has several suggestions for papers of this character to hand over to next year's committee as it was not feasible to procure them in time for presentation this year.

The committee also considers that it may render some service to the Institute in incorporating in this annual report a very brief statement of recent progress in the science and art of illumination, referring to a few of the most salient features of that progress, and not in any sense attempting to classify categorically the recent developments or even to suggest a true perspective. For such a presentation the members of the Institute are referred to the Report of the Committee on Progress of the Illuminating Engineering Society.

Progress in Electric Illumination

The marked progress in electric lighting in the past few years is founded largely on the reduced cost of luminous flux. The higher lamp efficiencies which have been realized in the newer electric lamps, together with the gradual decline in cost of power, have combined to cheapen luminous flux to such an extent that

Digitized by Google

the average customer can with advantage sacrifice cost to a moderate degree in order to enhance to a greater degree the satisfactoriness of his installation. On this thesis may be explained, at least in part, the tendency toward higher illumination intensities, both indoors and outdoors, the more general use of indirect or partially indirect lighting systems, and the demand for so-called "filtered flux," as in the lamp which supplies luminous flux approximating daylight in quality, or as in the yellow lamp or the various kinds of tinted glassware.

It is not intended to leave the impression that the lower cost of luminous flux from electric lamps is uniquely responsible for this marked development in artificial illumination practise. Along with this growing economy must be considered the important progress manifest in the increasing appreciation of the value of the newer ideas of illumination and the equally important progress in developing the means by which these more highly developed ideas may be realized in practise.

A few particular cases of progress may be mentioned. One of the more important of these is perhaps the approximate realization of the quality of daylight in artificial illumination, secured through the development of a special bluish bulb, which, at some sacrifice of the lamp efficiency, modifies by selective absorption the quality of luminous flux emitted by the gas-filled tungsten lamp, so that the transmitted flux has a spectral distribution of the same general character as sunlight. The practical possibilities of such a device are immediately evident. One of the most important applications is to be found in the lighting of museums of art,—an application which has recently been made with marked success.

"Flood lighting" constitutes another particular case of recent progress worthy of special mention. The application in the lighting of the Statue of Liberty is the most prominent illustration of this type of illumination, but it is being used in the most varied ways, many of which have marked practical value. In connection with flood lighting may be mentioned the recent activity regarding projection lamps in general, and the present prominence of the question of automobile headlights and other searchlights.

One other example of progress is to be found in the considerable increase in the use of ornamental "White Way" lighting for main business streets, and ornamental boulevard and residential street lighting. This, of course, has resulted in a general revising

Digitized by Google

of the standard of illumination throughout streets of lesser importance, but joining more or less closely the "White Way" districts. Along with the better lighting of business streets there is a gradual tendency to improve residence street lighting and to make better use of the light flux available on such streets by more rational subdivision of units and by utilization of light flux heretofore wasted for the lack of proper directing devices.

In closing this brief report reference should be made to the growing acceptance of the idea of legalizing lighting codes. Two years ago a Committee on Lighting Legislation of the Illuminating Engineering Society presented to the society a report containing a code of factory lighting. During the past year this code has been adopted and become a law in the states of Pennsylvania and New Jersey.

Automobile headlight glare which has been the subject of considerable legislation has in general been treated in a very unscientific manner until very recently. Now, however, there is decided evidence of an awakening among technical men on this subject and a better understanding of the problem to the end that satisfactory solution of the problem appears to be in sight.

E. P. HYDE, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON ECONOMICS OF THE ELECTRIC SERVICE

To the Board of Directors,

The Committee on Economics of the Electric Service submits the following report for the year of 1916-17:

During the past year this committee has carried on most of its work by correspondence, but there have been a number of the members who were conveniently situated with reference to New York City. The activity of the committee is best indicated by the fact that it had charge of the program for the Institute meeting on November 10th, 1916, the subject of the papers at that meeting being, "Effect of Recent Court Decisions on the Work of Inventory and Appraisal," by Philander Betts, Fellow; "Continuous Inventories, Their Preparation and Use," by Harry E. Carver, Member; "Growth and Depreciation," by Julian Loebenstein, Associate.

On April 14th, invitation was received from the Valuation Terminology Committee of the National Electric Light Association to send three representatives to the joint session of that committee with representatives of other societies, to be held on May 4th. As the result of the invitation, Mr. Clifton W. Wilder, Mr. Wm. B. Jackson and Dr. Philander Betts were designated to attend the same. Of these, Mr. Jackson was the only one who was able to attend, but Mr. Cohn was present, representing Mr. Wilder.

At the committee meeting referred to there were in attendance members of the National Electric Light Association, American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Gas Institute, American Electric Railway Association, American District Steam Heating Association and the Railroad Presidents' Conference Committee.

After considerable discussion as to the form of organization, the meeting should adopt, Mr. J. N. Shannahan was elected Chairman, and after a lively discussion, it was decided not to make any recommendations as to the formation of a joint committee at this time.

The definitions of the terms which the N. E. L. A. committee have prepared, were discussed and it was decided that each

Digitized by Google

person who was appointed to represent an association at the meeting should receive or be sent a copy of the definitions of the N. E. L. A. and of the A. E. R. A., and that each should be asked to send to Mr. Shannahan criticisms of the definitions: these to be manifolded and sent to each of those authorized to meet with the committee, so that there will be working material as a basis for discussion when the enlarged committee is again called together. The committee then adjourned to re-assemble at the call of the chairman.

The American Society of Civil Engineers has recently discussed similar definitions in connection with the discussions of appraisals. These definitions differ so greatly from the definitions accepted by economists, financiers and engineers, generally, that the importance of the work of this joint committee is at once apparent.

It is recommended that the committee be continued, with general instructions to continue its conference with representatives of the other societies.

PHILANDER BETTS, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON PROTECTIVE DEVICES

To the Board of Directors,

The Committee on Protective Devices submits the following report for the year 1916-17:

During the year two meetings have been held under the auspices of this committee; one at Boston on the rating of high-tension oil switches, and one at Chicago on protective relays for transmission systems. At the meeting in Boston it developed that the engineers were not all in accord as to how or whether oil switches should be rated in terms of the current which they could safely interrupt. A sufficient number of engineers, however, were in favor of such a method of rating to indicate that such a rating would be very desirable if possible. It is also to be noted that the edition of the National Electrical Safety Code, issued as Circular No. 54 by the Bureau of Standards, and dated November 15th, 1916, has a rule requiring that oil switches "be marked with the current which they can safely interrupt." It is recommended that this question be referred to the Standards Committee.

During the discussion on the relay papers it was brought out that there were several types of relays which were known by different names. One type of relay, which is more correctly called an excess-current relay, is generally called an overload relay, although it is not the best practise to use such relays on the generating or transmission system as a precaution against overheating due to slight overloads. They rather operate in case of large excess currents or short circuits, and there is no doubt but that their name has misled many engineers to use them improperly to the impairment of the service rendered by their system.

Another type of relay is variously called a reverse-current relay, reverse-power relay, reverse-energy relay, and unidirectional relay. This type of relay is intended to operate only with excess currents in one direction.

A third type of relay, used for connecting two transmission lines operating as one line with divided conductors of different constants, is variously known as biased relay, percentage differential relay, and ratio balance relay.

Digitized by Google

During the meeting in Chicago it developed that because of a lack of a conventional name, considerable space in the papers and time in the meeting was consumed in defining the terms used in the discussion. While it is entirely probable that the details of these various types of relays will be altered and improved from time to time, it is quite evident that the types of relays will endure, and it is suggested that the nomenclature of these several types of relays be referred to the Standards Committee.

The discussion on the relay papers in Chicago indicated that a number of the companies in the larger cities were rapidly changing their practise in the operation of transmission lines due to the development in relays. Heretofore most of these companies, in order to obtain localization of the trouble upon the breaking down of a transmission line, have operated their lines radially, that is, singly and not in parallel at the substation ends. This plan of operation confined the service interruption following a breakdown, to the load being carried on this transmission line. With the advent of the later types of relays, which have been developed by several manufacturing companies, a number of the central station companies are now operating their transmission lines in parallel in a number of combinations, as they find by experience that the relays are reliable for this service. This method of operating transmission lines in parallel results in a considerable economy in transmission line copper due to the diversity in the load on the various transmission lines. With the present high prices for copper, any development in relays which will permit greater economy in transmission line copper should be of interest to a large part of the Institute membership.

It also appeared from the discussion that some companies were using a simple, low priced relay and securing practically the same service as other companies with a higher priced, more complicated relay, and under practically the same conditions. It also appears that some companies are experimenting with types of relays under certain conditions, which have been tested by other companies under practically the same conditions and abandoned because unsatisfactory.

In view of this situation, which has been known to the committee for a number of months, but which was accentuated by the discussion at the Chicago meeting, the committee has undertaken to prepare a questionaire regarding relays, but owing to the circumstances during the past few months they have been unable to put this questionaire in form to be sent out to the various

Digitized by Google

power transmission companies. It was the hope that the replies to this questionaire would enable the committee to make some definite recommendations based upon the experience of the various companies. It is recommended that the work on this questionaire be continued by the Committee on Protective Devices during the coming year, and that the information gathered by the questionaire after being tabulated and summarized, be presented by the committee in form for discussion at one of the technical sessions of the Institute.

D. W. ROPER, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON INDUSTRIAL AND DOMESTIC POWER

To the Board of Directors,

The Committee on Industrial and Domestic Power submits the following report for the year of 1916-17:

At the October 1916 meeting of the Board of Directors the committee name was changed from "Committee on Electricity for Industrial and Domestic Use" to "Industrial and Domestic Power Committee." A rather large committee was selected, as the chairman desired to consider a new field of activity and wanted to get as wide an expression of opinion as possible.

Three meetings of the committee were held; the first in Philadelphia in October, the second at Pittsburgh in January and the third at Chicago in March. In addition a sectional meeting was called in Cleveland in December.

Of the twenty-two members on the committee 16 have attended one or more of the meetings and of the other six the chairman has personally seen and talked over the committee work with all but one.

The committee has been represented at every meeting of the Meetings and Papers Committee.

The presentation of papers under the auspices of the committee was confined to two sessions at the midwinter convention in February on the general subject of "Control of Industrial Motors." The committee responded well to the request for a list of papers available for presentation before local sections, and with the cooperation of other committees compiled a list of about 110 such papers.

In 1914 the committee started an investigation of standard sizes for carbon brushes. Up to that time no effort had been made along this line with the result that nearly 5,000 variations of sizes and special work were in use. The present chairman has actively followed this line and in 1915 interested the Electric Power Club. After a great deal of work on their part a meeting was called in Cleveland between representatives of the Electric Power Club and the Carbon Section of the Associated Manufacturers of Electrical Supplies, with the chairman of this Committee as the chairman of the meeting. Subsequent meet-

Digitized by Google

ings were held and the following standards have been adopted by the Electric Power Club as general engineering recommendations effective July 1st, 1917. It is recommended that the A. I. E. E. Standards Committee consider these and give their approval if nothing is found incompatible with engineering practise and development.

Standard Sizes for Carbon Brushes

1. Length of Round and Rectangular Brushes

Up to and including 1¼ inches.....increase by steps of ⅛ inch
Over 1¼ and to 3 inches.....increase by steps of ¼ inch
Over 3 inches.....increase by steps of ½ inch

Preference to be given steps of ¼ inch below 1 inch length and ½ inch above 1 inch length.

2. Width and Diameters

Up to and including ¼ inch.....increase by steps of 1/16 inch
Over ¼ inch to 2½ inches.....increase by steps of ⅛ inch
Over 2½ inches.....increase by steps of ¼ inch

It is recommended that ¼-inch steps be used wherever possible. Diameters of round brushes shall vary by steps of 1/16 inch.

3. Thickness

Up to and including ¾ inch.....increase by steps of 1/16 inch
Over ¾ inch.....increase by steps of ⅛ inch

It is recommended that ⅛-inch steps be used wherever possible above ½-inch thickness.

4. Limits

Rectangular and Square Brushes

Length.....plus or minus 1/32 inch
Width.....exact size down to 1/64 inch undersize
Thickness—Plain brushes.....plus 0.001 inch
minus 0.003 inch
Plated brushes.....plus 0.001 inch
minus 0.004 inch

For square brushes thickness limits to apply to both the width and thickness.

Round Brushes

Diameter:—
Up to and including ¼ inch.....exact size to 0.006 inch undersize
5/16 and ⅜ inch.....exact size to 0.008 inch undersize
7/16 inch and above.....exact size to 0.010 inch undersize
Length.....plus or minus 1/32 inch

Box gauges to be used for thickness and diameter.

5. Length of Shunts

It was decided that no standard lengths could be used, but it was agreed to define the length of a shunt as the distance from the top of the brush to the center of the slot or hole in the terminal.

Digitized by Google

6. Holes or Slots in Shunt Terminals

It was decided that exact sizes are not essential, but that the following shall be adopted as a maximum for the screws specified, and the minimum shall allow sufficient clearance to permit the screw entering the slot or hole without binding.

No. 8 and No. 10 screws..... 7/32-inch hole or slot
No. 12 and No. 14 screws..... ¼-inch hole or slot
5/16-inch screw.....11/32-inch hole or slot
⅜-inch screw.....13/32-inch hole or slot

7. Bevels

Bevels on carbon brushes shall vary by steps of five degrees and shall be accurate to within one degree above or below.

The length of a beveled brush shall be the distance from the end to the toe of the bevel, if beveled on one end only, or the distance from toe to toe measured parallel to the face of the brush when both ends are beveled. In other words the length will be that of the square-ended brush from which the beveled brush was made.

8. Plated Brushes

Dimensions, limits, etc., to be the same as for plain brushes, except thickness limits, for which see Paragraph 4.

The greater part of the year's work has not been finished but the committee hopes to have the papers ready for presentation next fall. It undertook to begin a study of motor and control application to various industries. It believes there is a best type direct-current motor, a best type alternating-current motor and a best type controller for every important machine in every industry. The committee has undertaken this year to begin a study of three fields; cement industry, passenger elevators and metal working industry. For this purpose three sub-chairmen were appointed, one in charge of each division. As stated above, the work is not completed but, if the committee is held largely intact for another year, it is believed we can make complete recommendations for the cement industry and passenger elevators. The metal working industry is too extensive to cover in such a short time and the sub-committee in charge of this division is making a study of some of the most important machine tools. The results are to be presented in convenient table form.

Care will be taken to keep recommendations of such a general nature that they will not discriminate between manufacturers. In every case where recommendations are made they will include both alternating and direct-current motors without favoring one over the other.

Digitized by Google

The committee enlisted the services of local Industrial and Domestic Power Committees and responses were received from Seattle, Milwaukee, and Cleveland with assurances that any work outlined by the committee would be carried out to the best of the ability of the local committee members. The Industrial and Domestic Power Committee recommends that a careful study be made to determine to what extent local and national technical committees can cooperate in their work to mutual advantage. It has been suggested that perhaps the technical committees depend too much on specialists and not enough on the vast fund of practical experience of the membership at large.

E. H. MARTINDALE, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON TELEGRAPHY AND TELEPHONY

To the Board of Directors,

The Committee on Telegraphy and Telephony submits the following report for the year 1916-17:

Cooperation in Avoiding Interferences

Cooperation between the representatives of lighting and power interests and the operators of telephone and telegraph plants, directed toward avoiding hazards and interference, has progressed, and the engineers of these different utilities are becoming better acquainted with the problems involved leading toward the friendly settlement of differences. Specific cases of interference are being met by the application of principles, some of which have been established as the result of experience and others which are in more or less advanced stages of development.

Telephony

Applications of the developments which made transcontinental telephony possible have been extended so that now the cities of over 50,000 population in the United States, as well as the territory adjacent to them, have been placed in telephonic communication with each other. These improvements which have increased the range of telephone transmission many-fold have been made with only slight changes in the lines and equipment and with no change whatever in the subscriber's station apparatus.

Beyond the advantage to the public of such a universal system of communication, its special value under war conditions, in problems of national defense, is of transcendent importance. This was demonstrated during the past year by a mobilization of systems of communication made at the request of the Secretary of the Navy. This demonstration was conducted in cooperation with naval officers under the command of the Chief of Naval Operations. Continuously during three days the Navy Department at Washington and the Navy Yards and Naval Stations in the Continental United States carried on all their communication with each other and with the naval force in that territory by

Digitized by Google

telephone and telegraph over the wires of the Bell System. During this period instantaneous telegraph and telephone communication between any points involved in the mobilization was possible.

Included in this demonstration was a test of wireless telephony. The battleship New Hampshire was connected with the system by wireless telephony and was able to receive and send communications while the vessel was at Hampton Roads and even as far out to sea as the southern drill grounds. Conversation between the Mare Island Navy Yard on the Pacific and the battleship New Hampshire while at sea was possible. Captain Bennett, in command of the Mare Island Navy Yard, conversed with Captain Chandler on the New Hampshire which was at that time in a storm on the Atlantic. This conversation was transmitted over the transcontinental telephone wire circuit from Mare Island, California, to the radio station at Arlington, Va., and there transferred automatically to the wireless from Arlington to the ship at sea, the return conversation taking the opposite course.

The mobilization was intended primarily to test the efficiency of the wire system in time of war. The Secretary of the Navy and the Admiral in command at Washington talked to the commanding officers of the naval stations on the Pacific coast, on the Gulf and Atlantic coasts and on the Great Lakes. The results of this mobilization were most satisfactory and demonstrated that the plant and organization involved were in complete readiness to respond in case of national emergency.

TELEGRAPHY

In the subject of telegraphy, beyond the increasing use of automatic devices and methods, there have been no new developments completed concerning which reports can be made at this time.

RADIO-TELEGRAPHY

Along the lines of commercial application of radio-telegraphy there has been an extension in the long distance service by the Marconi Company opening up communication with Japan via Honolulu. There are also high powered U. S. navy stations located in California, Hawaii, the Canal Zone and the Philippines. The two German stations located at Sayville and Tuckerton have done a large business in transmitting messages to and from Germany directly.

Digitized by Google

The tendency in radio-telegraphy in its use on ships has been towards standardization in the form of the sets. This is particularly true in the spark type of sets. There has been an increasing use of sustained waves on ship stations. The general service rendered by the ship stations has continued to be of large and increasing value.

The use of sustained waves is increasing. The power required for this method is generated by arcs or by high-frequency alternators either directly or through frequency transformers.

F. L. RHODES, *Chairman.*

Digitized by Google

ANNUAL REPORT OF THE MARINE COMMITTEE

To the Board of Directors,

The Marine Committee submits the following report for the year 1916-17:

The shipbuilding industry has been submerged with work both of the merchant variety as well as the naval type of vessel. Heavy demands have been made upon the time and talents of the electrical engineer. New and extensive applications of the electric motor have been made. Many of the merchant designs have departed from the conventional direct-current lighting plant to a complete equipment of alternating-current lighting and motor service including engine room as well as deck auxiliaries. These plants have followed commercial land practise using 250-volt, 60-cycle, 3-phase alternating current. Two or more merchant vessels now under construction will be electrically propelled. The navy preparedness program included over one hundred and fifty vessels and the capital ships are to be electrically propelled.

Present Activities

The rules for marine installations compiled last year and adopted by the National Board of Fire Underwriters were accepted this year without change by the American Bureau of Shipping. These rules were simultaneously submitted to Lloyd's Register of British and Foreign Shipping and their representatives in this country suggested that our committee confer with the British Institution of Electrical Engineers. We are at present in correspondence with the rules committee of the British Institution and are awaiting ways and means of accomplishing the final acceptance of Lloyd's Register. This acceptance will complete the work of standardization of marine installations. A sub-committee was appointed at the beginning of the year to consider tentative rules for the installation of wires and wireways specifically for electric propulsion but this sub-committee in a partial report indicates that the subject cannot be well handled while the designs proposed are still in an unsettled state. One technical paper has been in course of preparation since last August and three other papers were requested. The stringency of the times has not permitted the writers to effect an accom-

Digitized by Google

plishment. The confidential restrictions placed on naval affairs forbids the publication of technical data at this time and this committee is of the opinion that general or suggestive papers would not be of value to the TRANSACTIONS of the Institute. The applications of electricity to the merchant service are in the nature of innovations and their value remains for determination after their performance has been carefully observed in practise.

FUTURE SUGGESTIONS

The unfinished negotiations with Lloyd's Register of British and Foreign Shipping should be brought as soon as possible to a favorable conclusion. The preparation of tentative rules covering the installation of electric propelling machinery and correlated matters should be entered upon as soon as opportunity permits, so as to avoid restrictions or complications that may take place due to lack of rules or the transfer by interpretation of old rules to a new and not fully understood application. Continuity in committee work is essential to progress and the chairman of this committee has consistently laid before the secretary of the committee all matters connected with the actions both external and internal of the committee so that full information is available to the succeeding committee. It is believed that sub-committees which have not been able to complete their work should be continued until discharged. In view of the conditions briefly alluded to it seems almost impracticable at present to suggest any methods for the production of technical papers. It may be expected, however, that in a few months the conditions may change, sufficient experience gained, and results obtained, to allow of the collection of much valuable information for the TRANSACTIONS.

H. A. HORNOR, *Chairman.*

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON THE USE OF ELECTRICITY IN MINES

To the Board of Directors,

The Committee on the Use of Electricity in Mines submits the following report for the year of 1916-17:

Principal Developments in the Use of Electricity in Mines

The more notable advances in the use of electricity in mines during the past year have been in the directions enumerated below:

The development of storage-battery locomotives and combination storage-battery and trolley locomotives.

The development of trolley locomotives in sizes up to 35 tons.

The development of the so-called "arc-master" for use with mine locomotive controllers.

The increased use of power purchased from central stations.

The application of electric motors to the ventilating fans of coal mines.

General improvement in the design and construction of mine electrical equipment, and increased use of interpoles and improvement in the methods of impregnating motor windings to make them moisture resisting.

The increased use of 2200 volts and higher voltages for underground transmission and for direct application to stationary motors used in mines.

The development of explosion-proof motors for coal mines.

The development and widespread adoption of self-contained portable electric lamps for miners. (This is believed to be one of the most effective safety measures that has been taken in some time).

The development of a practical electrically operated reciprocating drill.

The increased use of electrically operated coal cutting equipments.

Increased interest in safe electrical equipment and measures for safeguarding the use of electricity in mines.

Digitized by Google

Activities of the Mines Committee

The Mines Committee was reorganized rather late in 1916 and for that reason has not accomplished as much as the members could have desired. The committee has recommended to the Institute that active steps be taken to increase the membership of the Institute among electrical engineers engaged in mining work. They have also recommended that a vocational classification be made of the membership of the Institute, to the end that all technical committees can readily determine what engineers are interested in the particular work of the committee.

The committee has also recommended that meeting at which mining papers are presented should be the meeting held at Pittsburgh, or one of the sessions of the Mid-Winter Convention, in the event of the Mid-Winter Convention's being held simultaneously with that of the American Institute of Mining Engineers. The committee points out that under no other circumstances can we be assured of an audience sufficiently interested in mining subjects to warrant the committee in asking the more prominent mining electrical engineers to present papers.

The principal work of the committee has been done in connection with suggested rules for the use of electricity in bituminous coal mines. These rules were prepared by two members of the committee in collaboration with a majority of the rest of the committee and other mining men and electrical engineers. The rules were prepared under the supervision of the United States Bureau of Mines, who stands sponsor for them. These rules were formally submitted to the Institute by the Mines Committee, with a request that they be approved and adopted by the Institute. The rules were referred first to a joint committee of the Standards Committee and the Code Committee, who found that there was nothing in the rules incompatible with the Institute's Standardization rules. The Mines rules were then referred to a joint sub-committee composed of members of the Mines Committee and Standards Committee, who reported favorably upon them to a joint session of the Standards Committee and the Mines Committee, and the joint session recommended to the Board of Directors that the Institute approve these rules in the interests of safety, good engineering practise, and standardization. The Board of Directors then referred the rules once more to the Code Committee, which at the date of writing this report still has the rules under consideration.

Digitized by Google

Suggested Future Activities

It is suggested that the aim of the Mines Committee in the future be to get nearer to the electrical mining men, to urge the Institute to do things to interest such men and attract them to membership in the Institute.

An effort should be made to recruit the Institute ranks with as many of such men as possible and have mining sessions at which the best electrical men in the industry present papers. The time for such a move was never more opportune. It is suggested that if the Institute will interest itself in standards for mine safety and other mine electrical standards such an attitude will do more than anything else to interest a class of members that the Institute needs very much.

H. H. Clark, *Chairman.*

Digitized by Google

ANNUAL REPORT OF IRON AND STEEL COMMITTEE

To the Board of Directors,

The Committee on the Iron and Steel Industry submits the following report for the year of 1916-17:

The Iron and Steel Committee is arranging to cooperate, if possible, with the Association of Iron and Steel Electical Engineers for providing papers for their annual convention in September. Details of this cooperation have not yet been worked out.

From a study of the relations between the A. I. E. E. and the A. of I. & S. E. E., it is evident that it is desirable to formulate some kind of policy for the A. I. E. E. to follow.

The A. of I. & S. E. E. came into existence about ten years ago, as at that time it was thought by the mill operators that the activities of the A. I. E. E. did not cover the field in a way helpful to them. It was, therefore, decided to form an independent association that would deal with the problems of steel mill operators in a proper manner. The only persons eligible to full membership are electrical superintendents of steel mills or other plants allied with the steel industry. Members of manufacturing companies are only eligible for associate membership and take no part in voting.

It is evident from a knowledge of the constitution of the two societies that there is a natural division between their activities. The A. of I. & S. E. E. is primarily interested in the collection and exchange of data relating to operations. Such data are of interest only to persons interested in the steel industry. The A. I. E. E. is interested in the development of the electrical apparatus generally and questions of design of apparatus and special functions are of interest to many of its members. The information that may be obtained from papers and discussions is of interest to the whole industry whenever it contains an element of more than local application. It would, therefore, appear that as far as papers are concerned it would be natural for those covering operating features or special methods of installation, operating costs, etc., would be within the province of the A. of I. & S. E. E. Papers dealing with the design of the apparatus or with the relation of apparatus used in steel mills

Digitized by Google

to apparatus used in other industries, would naturally appear to be within the province of the A. I. E. E.

There are, of course, many points at which there may be a conflict. For instance, a paper dealing with the interconnection of a number of independent generating stations in steel mills so as to utilize their combined capacity to better advantage, would be a natural subject for discussion before the A. of I. & S. E. E. On the other hand, such a paper would also be of interest to the A. I. E. E. as it relates to a problem which is an every day matter of power generation and distribution. There are bound to be a number of such papers read before both societies. On the other hand, a paper dealing with the design of a rolling mill motor would naturally be the subject for the A. I. E. E. as a rolling mill motor is only a special form of one class of electrical machinery. However, the paper dealing with method of installing such a motor and the peculiar conditions under which it might operate would be proper subject for the A. of I. & S. E. E., as it would only be of interest to the members of this association and not the membership of the A. I. E. E. generally.

In this connection, it must be borne in mind that the majority of full members of the A. of I. & S. E. E. are members of the A. I. E. E. and it is also a fact that practically every one in the A. I. E. E. interested in the steel industry are members or associates of the A. of I. & S. E. E.

This matter has been gone into at some length as it would appear advisable for the A. I. E. E. to adopt a fixed policy regarding acceptance of papers to be read before it on subjects dealing with the iron and steel industry.

An important activity of the A. I. E. E. is being duplicated to some extent by the A. of I. & S. E. E., *i.e.* Standardization. It does not appear that it is advisable for the A. of I. & S. E. E. to attempt a standardization of apparatus in competition with the A. I. E. E. but it would appear desirable for the A. of I. & S. E. E. to adopt the standards of the A. I. E. E. and to have a sub-committee of the A. I. E. E. Standard Committee to take care of any special characteristics that may be found necessary for the successful operation of apparatus in the steel industry. In this way a useless duplication of the work can be avoided and also the natural confusion that will arise regarding requirements if there are several standards. The manufacturing companies are certain to adhere to the A. I. E. E. standards and there

Digitized by Google

would be continual difficulty regarding exceptions to any other set of standards.

It would appear that there is a field of activity in the steel industry that should be probably covered by the A. I. E. E., but at the same time an effort should be made to avoid the presentation of papers which interest only a small section of the Institute membership and which would be more effective if read before an association all of whose members would be interested in the subject. It is, however, desirable that an effort be made by the A. of I. & S. E. E. to avoid unnecessary attempts at standardization if the same result can be obtained by cooperation with the A. I. E. E.

It would seem desirable that a small committee of the A. I. E. E. should be formed to confer with a similar committee of the A. of I. & S. E. E. to arrive at an understanding regarding the activities of each society in connection with the iron and steel industry. In this way a definite settlement can be arrived at and a policy fixed for the future. The A. I. E. E. committee should preferably consist of members not associated with the iron and steel industry. All members of the A. I. E. E. connected with this industry are necessarily more or less associated with the A. of I. & S. E. E. and it is rather difficult for them to differentiate between the claims of the two societies.

WILFRED SYKES, *Chairman.*

Digitized by Google

ANNUAL REPORT OF THE EDUCATIONAL COMMITTEE

To the Board of Directors,

The Educational Committee submits the following report for the year of 1916-17:

The Educational Committee has devoted its attention to the subject of devising a scheme to assist and encourage the younger members of the Institute in developing themselves by undertaking the study of research and practical problems which it is hoped will be collected for them by the Educational Committee in the future from the older members of the Institute and presented in the form of competitions. In doing this your committee has been carrying forward and enlarging the policy of the Educational Committee of the preceding years.

It is the sense of your Committee that the Educational Committee should endeavor to assist the younger members of the profession to improve their training in engineering by carrying on volunteer graduate work of a practical character under the advice of the older members who are in the active practise of the profession.

There is apt to be a gap in the intellectual training of an engineer from the time he leaves his technical school, while he is engaged in the important but ruder type of work of the shop or field, till he has "found himself" and made a sufficient reputation to be taken into the office and put upon the higher problems of engineering. During the time of this gap numerous young men feel a want, a longing to do something which will improve themselves and give them an opportunity of demonstrating their capacity to the older members of the profession. At present only the exceptional ones have sufficient originality and progressiveness to think out problems for themselves and tackle them. The majority of the good men devote their spare hours to reading and the remainder just drift along.

While reading and study will develop one's knowledge it will not develop originality, inventiveness and resourcefulness. Only the application of knowledge to specific problems will do that.

The young men in this category are particularly the younger members of the Institute forming the substantial part of the membership of the "Branches," but also the enrolled students

Digitized by Google

and students in technical schools should be considered. The Institute should consider that these men cannot attend the general meetings very frequently and that the majority of the papers presented before these general meetings are too specialized to appeal to them. Yet these men are the future backbone of the Institute and the profession. It is therefore the duty of the Institute to hold their interest and train them. This is a matter which should interest the Sections Committee also and should aid in strengthening its work and it also can aid in carrying on this work.

Thus your Committee urges a cooperation between the Sections Committee and the Educational Committee in the work of providing programs of papers and study for the younger members through the medium of the branches.

The committee has sketched out a scheme of action which it recommends should be developed and followed up by successive Educational Committees throughout a term of years.

The program should begin with a meeting of the Institute devoted to this subject for which papers would be invited from a few of the older men which should deal with the subject of what qualities and training after graduation are most valuable in the young engineering graduate. A few written discussions of the main papers should also be invited. At the same meeting there should be presented some letters from the younger members stating their point of view and the obstacles they encounter in the way of advancement.

The Educational Committee should collect suggestions for research and hypothetical problems of a practical and theoretical nature from older members and present them to the membership through the medium of the branches. Work on these problems should be organized in the form of competitions similar to those carried on successfully for a number of years by the Engineer's Society of Western Pennsylvania. The committee acknowledges the helpful and valuable suggestions imparted to it on this subject by Dean Leete of Carnegie Tech. School. To carry out this scheme the Educational Committee should actively solicit suggestions from the older members and should send out from time to time a list or program and announce a time at which the solutions would be considered and graded. The Educational Committee should assume the responsibility of grading these reports but should appoint judges from engineers outside of its membership. Later the most praiseworthy solutions should be

Digitized by Google

published and a meeting of each of the branches set for the discussion. If possible awards should be made for the best solutions although it is probable that the honor of having the paper published and discussed would be a sufficient incentive.

The Educational Committee from time to time should invite prominent members of the Institute to write papers on fundamentals or principles of the design and operation of electrical apparatus or systems which would make our proceedings of more interest to the younger members. As examples of papers of this character are two by Mr. B. G. Lamme on Commutation, 1911, and on Iron Losses in D-C. Machinery, 1916.

Your committee recommends that relations be established with the Educational Committees of the other three Founder Societies for an exchange of views and coordination of methods as we understand that the A. S. M. E. is endeavoring to carry out a similar policy to strengthen its hold on the younger members through the cooperation of the Educational and Sections Committees.

In general the plan outlined is intended to supply the missing link in the development of the engineer between the time of graduation and the time he really begins to accomplish something and becomes an identity in the engineering profession.

W. I. SLICHTER, *Chairman.*

Digitized by Google

ANNUAL REPORT OF THE POWER STATIONS COMMITTEE

To the Board of Directors,

At the first meeting held October 13, 1916, the scope and activity of the Committee were analyzed with a view of avoiding the present unnecessary duplication found in the numerous committees of the various sister societies. The opinion has been advanced that many of the overlapping committees would do better to limit their work to the subjects peculiarly proper to their own society, and omit the investigation of subjects falling more nearly in the work of other societies, utilizing the work of sister society committees to complete the field when necessary.

For instance, the design of turbines, stokers, bearings, and boilers is very properly the work of the A. S. M. E. It is a waste of time for the A. I. E. E. to go through all the work of the Boiler Code again: Therefore, the boiler code of the A. S. M. E. was offered to the standards committee with the recommendation that it be approved, since, presumably, the Mechanical Society should be the highest authority on a mechanical subject. Action has been deferred for the present. In the opinion of the committee the right move has been made on subjects common to several societies in the formation of the joint committees on the cost of electric power.

With the above in view, a resolution was passed (a) that the function of this Committee is to investigate and report on the engineering of power stations beginning at the prime mover and ending at the outgoing cables; (b) that the investigation of specific problems on the remainder of the power stations, and allied engineering affecting it, shall be formally referred to appropriate committees of sister societies for action. This Committee will utilize the resulting action of such sister societies in completing its own reports. This Committee believes in usefulness of joint committees in getting the full results on a subject covered to the best advantage by each society in its own special field as far as is practicable.

The subjects offered for investigation are given below.

(1) *Safety First Work in Regard to Arrangement and Installation of Apparatus*: This was referred to Mr. Torchio, who has

Digitized by Google

reported that the reference material on this subject was already very fully covered by the National Electric Safety Code and the Fire Insurance Companies.

(2) *Combined Hydraulic and Steam Plants*: This was thought to be a subject of special solution in most cases, but a committee consisting of Mr. Scattergood, Mr. Harisberger and Mr. Meredith was appointed to get up a paper on the economics and design of hydroelectric and steam developments.

(3) *Excitation*: This subject was taken up broadly, the original suggestion only covering the use of the combination electric-steam-drive unit now becoming popular. A committee consisting of Mr. Wallau, Mr. Wood and Mr. Harisberger and Mr. Kruesi, Mr. Smith later substituted for Mr. Kruesi, on account of the latter's ill health.

A preliminary report has been prepared, which will in all probability be submitted in final form by September.

(4) *Methods of Heat Analysis and Distribution for Steam Power Plants*: Mr. Pigott, Mr. Gorsuch and Mr. Wood form the subcommittee and were instructed to cooperate with the N. E. L. A. Prime Movers Committee. Upon attempting this, it was found that the N. E. L. A. Committee thought its work was too far along to make it advisable to modify their report, but it will be used in working up ours. A paper on the subject is to be ready by September.

(5) *Air Conditioning for Generators*: Dr. Moss, Messrs. Lincoln, Moultrop and Torchio were appointed to investigate the status of the air washer and filter for generators. Preliminary report, March 17th, shows that while the advantages of air conditioning are undoubted, the results obtained do not always justify the expense of the equipment, on account of inefficient working of the washer. The committee is not satisfied with the data at present on hand, and is collecting further information.

(6) *Rating of Switches and Breakers for Dusty or Dirty Atmosphere*: The question of cutting the rating of switches and breakers in cement and cereal mills, or other dusty atmospheres, was brought up by Mr. Drabelle. It was the opinion of the Committee that this subject should be referred to the Committee on Standards, which was done.

(7) *The Ford Power Plant*: On examination of Mr. Allison's paper it was thought desirable that some actual operating data from this plant should be given, rather than predictions, and the matter was therefore laid aside for the present.

Digitized by Google

(8) *Improvement of Waterwheel Test Code*: The opinion of the Committee was that the problem should only be attacked from the electrical end by way of known generator losses, etc., leaving the mechanical end to be handled by the A. S. M. E. and the N. E. L. A. in whose hands it more properly belongs. Mr. Lincoln, with Mr. Egbert, and Mr. Reist, were appointed to handle this matter. No report up to the present.

(9) *Design of Mimic Switchboard*: This subject was brought up by H. R. Parker of the Toronto hydroelectric system; he was referred to several companies using these boards, as it was thought committee work for immediate construction purposes would be too slow.

The chairman of the Committee, Mr. DeRemer, has been forced to relinquish this work for the present on account of being called to Washington on Government work. The writer was appointed to carry on the work and wishes to apologize for any shortcomings of this report, as it has been prepared on notice too short to allow of bringing all sub-committee's reports up to date.

R. J. S. PIGOTT, *Vice-Chairman*.

Digitized by Google

ANNUAL REPORT OF COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY

To the Board of Directors,

The Committee on Electrochemistry and Electrometallurgy submits the following report for the year 1916-1917:

In the absence of Capt. T. H. Schoepf on military service the following brief memorandum on the work of the Electrochemistry and Electrometallurgy Committee, has been compiled from the files of the chairman, with the hope of giving the new committee and chairman the benefit of the suggestions and opinions of the retiring committee.

No sessions on electrochemical subjects were held during the year as none of the papers reviewed by the committee, were suitable for presentation except at joint meetings with the American Electrochemical Society, and such joint meetings could not be arranged because of conflicting dates.

It was Chairman Schoepf's plan to work up some good papers for the coming year and he made an endeavor to find out from the most prominent engineers in the electrochemical industries, what subjects should be considered by the committee and presented before the Institute or before a joint meeting with the American Electrochemical Society. The replies to the first request by the chairman and the subsequent opinions of the members of the committee, on suggested subjects, seemed to indicate a wide difference of opinion regarding the advisability of presenting some of the proposed papers.

The most popular suggestions were electric furnaces and the fixation of nitrogen, however some of the electrochemical specialists feel that papers on these subjects, which have been treated repeatedly by other societies, would result in duplication, unless some hitherto untouched phase of the subject is to be dealt with.

Other subjects which have been suggested and discussed by the committee are: electrical porcelain, electric cells and batteries, electrolytic copper, conductors of copper vs. iron vs. aluminum, coal vs. water power for electrochemical industries.

The last subject, seems from the correspondence, to be worthy

Digitized by Google

of careful study and of great interest to both the steel and electrochemical industries, in view of the recent developments in large steam power units and the water power restrictions imposed by the Government.

It is the suggestion of the retiring chairman and some of the members of the committee that this timely subject be taken up by the new committee and presented before a joint meeting with the American Electrochemical Society.

Another suggestion which met with approval was to have Mr. Liljenroth present a comprehensive paper on nitrogen fixation including the Norwegian practise, if the proper approvals can be obtained and there is no military objection to discussing the processes in the coming year.

L. W. CHUBB, *Secretary Meetings and Papers Committee.*

Digitized by Google

Digitized by Google

Presented at the Special Meeting of the American Institute of Electrical Engineers, New York, June 27, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

THE ENGINEER'S DESTINY

PRESIDENT'S ADDRESS

BY H. W. BUCK

THERE has been much discussion concerning the position of the engineer in modern times, but conditions are changing so rapidly and points of view are undergoing such a fundamental evolution that it is well from time to time to review the relations of the engineer to his surroundings and to secure if possible the proper orientation.

The change and improvement in the engineer's position in the world in recent years has been so rapid as to surprise even those who were the optimists in the under-dog days of the engineering profession. In the middle of the last century, when the engineering and technical schools began to be formed in this country by men of far-seeing vision, the classical scholars looked on askance and took pains to differentiate these upstart institutions from their own traditional schools of learning and to ostracize those who pursued the new courses by classifying the professions as "learned" and technical.

Times fortunately have changed. The engineering profession is coming into its own. To-day the engineer is being swept along with an irresistible force, by a tide which he himself has created, and it is well therefore for the engineer to take his eyes off his work occasionally and to observe his constantly changing surroundings. A flood of scientific and technical accomplishment has swept over the face of the earth, revolutionizing life, commerce and international destinies. Even the turmoil in which the world now finds itself can probably in the last analysis be traced to the over acceleration of world affairs resulting from the work of the scientist and engineer.

During all this development period of the engineering profession during the past century the engineer has worked his way along alone and in silence, so to speak, seeking his reward rather in the joy of accomplishment and in the realization of his dreams

Digitized by Google

than in worldly recognition and accumulation. The very inherent greatness of the pioneers who have laid the foundations upon which we now build prevented them in a way from acquiring a more worldly position in affairs. This tradition, however, is not a virtue beyond a certain point, and the engineer by nature is too willing to give way to others. The time has come when he should take a more worldly position in the world which he himself has created.

In our general relations to intellectual development we may consider that we are just emerging from a classical period where tradition, custom, prejudice, ignorance and dogmatic religion were the controlling forces. Movements which took place in world affairs were largely political, following the paths best suited to the advantage of the ruling classes. There was little real progress, because there was no development of scientific knowledge and its application in engineering. Scientific truth held no standing. The worship of tradition caused a powerful reaction against any scientific discovery which might necessitate a readjustment of established habits of thought and life.

For centuries before the dawn of the scientific and engineering era great changes took place throughout the world, but little real progress occurred. Races rose and fell, always falling back to the starting point, for there can be no upward trend in racial development without the solid basis of scientific knowledge to grow upon. China made great progress and developed its early civilization under scientific activity but during recent centuries it has lived under the worship of classical tradition and has become inert.

A constant change in point of view, which is so largely brought about through developments in scientific knowledge, seems to be necessary for progress in civilization. Our civilization to-day differs from that of a century ago in proportion to the scientific and engineering evolution which has taken place during the period through its reactions on life in all of its phases. Such discoveries in science as the law of gravitation, the evolution in species, the laws of electro-magnetic induction, etc., have probably had a more profound effect upon the development of the human race than any other acts in history.

The engineering profession has passed through the preliminary stages of its growth and has reached a position where the engineer should work and act not only with proper attention to his work itself but with full consciousness of the important relation of his

Digitized by Google

work to human affairs in general. Among the early pioneers in engineering were many notable instances of men of great breadth of view. Men like Watt, Fulton, Whitney, McCormick, Erickson and others. Specialization had not at that time begun to work its narrowing influences. Of recent years, however, under the stress of commercial development and economic conditions, increasing specialization has taken place and the engineer has become obliged to compass his mind with an ever narrowing horizon. This specialization produces extraordinary proficiency in particular fields, but has the objectionable effect of narrowing the character and outlook of the man and of reducing his value as a citizen. We must take care lest commercial considerations and the modern mania for efficiency in the narrow sense does not force our engineers to lose sight of the world around them in their concentrated attention to the part rather than to the whole. This excessive specialization is a danger which threatens the future standing of the engineer.

It is interesting to recall in this connection the results of a recent canvass made by a joint Committee on Education on the qualities which, in the opinion of some five thousand leading men, engineers and others, best fitted a man for a successful career as an engineer. As a result of this vote only 13 points out of 100 were assigned to purely technical knowledge as an essential, the other 87 points being allotted to broader qualifications such as judgment, character, human understanding, etc. This is merely a quantitative statement of the many general demands now being made of the engineer and it illustrates how the work of the engineer can be broadened out. It is an encouraging symptom.

A most significant movement of recent times in the engineering world has been the development of cooperative action among engineers of all classes, and this tendency will, I believe, serve to offset the evils of specialization. It is the growing recognition of the fact that all branches of engineering are interdependent. We electrical engineers, I believe, are well aware how much we need the assistance of other branches of engineering for the successful fulfillment of our purpose.

This cooperative movement has quite recently been given tangible expression in the formation of the Engineering Council, an act, I believe, of far-reaching consequence. Under this organization as a beginning the Civil, Mechanical, Mining and Electrical Societies together with the United Engineering Society are

Digitized by Google

tied together for cooperative action through a joint body of twenty-four representatives. This body will meet at frequent intervals and will deliberate on matters of general interest to engineers. It is an encouraging beginning toward universal cooperation among engineers in all branches of work.

In this Engineering Council we have for the first time an engineering body representing some thirty thousand engineers of sufficient scope and standing to create an engineering public opinion. Its influence is likely to be far-reaching in building up the prestige of engineers in both technical and civic affairs.

A further development which has reached full recognition only in recent times is the mutual appreciation which has grown up between the engineer and the worker in pure science. The engineer looks to the scientist to provide him with raw materials of knowledge with which to work out his applications, and the scientist must look to the engineer to make his discoveries so fruitful that the full effectiveness of his work on the frontier of research can be sustained. Both are working together in order to unfold nature in the most effective way for the benefit of man.

We electrical engineers, I think, feel a particularly close bond with the pure scientist in that recent developments in physical science have disclosed an intimate relationship between electrical phenomena and the nature of energy and matter.

All of the important movements which are taking place at the present time, which center around the engineer and his work mean, I believe, that the engineer is soon going to leave his position of isolation in independent fields of work and realize that he owes an obligation to the community broader than his daily engineering work, and will contribute to the general welfare his talents and experience. It matters not whether the problems before him are political, sociological, industrial or technical, I believe that the engineering type of mind, if the proper breadth of view has been acquired, is best fitted to undertake them.

It is not necessary, perhaps, in important administrative positions to have civil, electrical or mechanical engineers as such, but we do need men in those positions who have had training of the type which engineering gives, with the mental balance, the power of analysis which such a training develops, the resourcefulness and the faculty of recognizing and properly apportioning the various elements in a problem. There is a quality of mental honesty which engineering experience highly develops which is

Digitized by Google

sorely needed in public life. The scientific and engineering professions should rise up and furnish such men from their ranks for the best welfare of the country.

The classicist contends that a world dominated by scientists and engineers would be cold, materialistic and atheistic and lacking in those qualities of art and sentiment and the imaginative outlook which every civilization so highly prizes. To this doctrine and its injustice to the engineer I want to take emphatic exception. The world today may be inclined toward materialism but it is not dominated by the engineer, far from it, but by other classes. The engineering mind on the other hand is characterized by a highly developed creative imagination and possesses to a high degree exactly those qualities of mind and temperament best suited to combat materialism. There have been many instances in history of great artists who have been great engineers and vice versa, and I believe that the two temperaments lie in close relationship. Furthermore, scientists and engineers as a class, have a strongly developed spirit of international understanding and sympathy which may serve as an important safeguard against excessive nationalism and aggression.

And so, gentlemen, I believe that we can confidently look forward to a new era for the proper fulfillment of the destinies of the engineer. Out of this world chaos we now see men of engineering and scientific training rising to positions of commanding prominence on all sides. It is simply the working of the inevitable law of the survival of the fittest.

In this great movement not only must the individual engineer play his part, but the great engineering societies must realize the power of influence which they are developing in an ever increasing degree in the community and the obligations which devolve upon them.

And so I hope that the American Institute of Electrical Engineers as it passes along from one administration to another will acquire an increasing realization of its duty, not only in furthering the growth of science and engineering, but in furthering the influence of the engineer in the affairs of the country and of the world.

Digitized by Google

Digitized by Google

Presented at the Special Meeting of the American Institute of Electrical Engineers, New York, June 27, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

ADDRESS BY PRESIDENT-ELECT E. W. RICE, JR.

IT GIVES me great pleasure to meet you here tonight and to be thus introduced as your President-Elect. I thank you, and through you, all the members of our great Institution, for the honor which you have conferred upon me in selecting me to be, for a time, your official leader and chief servant. I hope I may have the strength, the ability and the opportunity to render such service as to justify, in some measure, your confidence. I fully appreciate that, with such a great honor, is coupled an equally great responsibility and I value the position as an opportunity to be of service to you, and through you, to our Country.

The standard set by the long line of illustrious and industrious men who have already filled the position of President, will be constantly before my eyes and will, you may be sure, stimulate me to do my best.

It is a great satisfaction to feel that, by a wise custom of our Institution, President Buck and Ex-President Carty will remain on our Board of Directors throughout the term of my administration. I shall lean heavily upon them for their experienced counsel and assistance.

No body of men can get together at the present time without soon discussing the subject of the war, which is uppermost in everyone's mind.

The war is the one dominating factor in the world life and thrusts itself before our thoughts whether we wish it or not. We are in the war at last and will remain in it to the end. Whether it shall be a bitter end or a bright end will depend largely upon ourselves, as it is now our war.

It has been stated many times that modern war was largely a question of mechanics and engineering, a statement with which we must all agree. It is self evident that engineering must, therefore, take a leading and dominant position in the war work. Now the electrical engineer stands for about the latest thing in engineering development; his activities embrace practically all other fields of engineering, being, so as to speak,

Digitized by Google

the last word in engineering. The electrical engineer must, therefore, realize that this is his war in a very personal and particular sense.

War calls for supreme sacrifices and the deepest devotion, but it also demands something more difficult to give, and that is *work*. War may be said to be the personification of work, not only individual work, but especially organized and disciplined work,—disagreeable, dirty, heartbreaking, backbreaking, nerve-racking work, but always work. No nation of loafers ever won a war. Other things being at all equal, that nation or people who are willing to work the hardest will surely win the victory. Now I wish to point out that the enemy we are fighting is recognized as the most industrious organization in the world. Our enemy has prepared for war for fifty years and has been working with ever-increasing energy ever since the war started three years ago. We made no adequate preparation during all this time and therefore started with a fearful handicap of lost time and lost opportunities. We must not delude ourselves that our enemy is exhausted, but remember that he has the advantage of a flying start. We must accelerate at an incredible rate if we are to get our war-motor going fast enough, soon enough to catch up.

Our enemy boasts that we have started too late. We must, by the hardest work directed with scientific skill and accuracy, organize and effectively utilize all our power of work to make his prophecy an idle boast.

The country is trembling with eager anxiety to help. Men and women are offering their services and their money. All eyes are turned toward Washington and to many everything seems confusion, and as a result, we are full of criticism. Now I think it is clear that nothing is to be gained by destructive and captious criticism. We must discipline ourselves with patience, and if we take a broad view, we must admit that progress is being made. We must remember that a democracy of a hundred million people, whose thoughts and habits have been entirely those of peace, cannot change to the methods of war in a day, or a month, or even a year.

War is a business and must be handled as a highly organized, centralized, autocratic enterprise. We must, no matter how repugnant it may be to our habits and thoughts, temporarily adopt such methods of our enemy as are known to be efficient and successful, because the penalty of failure is death. War

Digitized by Google

is so repugnant to our ideals that it takes time to realize the necessity for and make the collosal changes demanded in every direction. We must, therefore, as I have stated, avoid captious criticism and confine ourselves to constructive crticism, and that sparingly and sympathetically administered.

There is one idea which we must abandon. The great majority of our people, who have no acquaintance with science or engineering, is prone to imagine that this war will be settled quickly by some wonderful new invention, as if by an act of legerdemain; but you engineers realize that such a thing is practically impossible. It is so hopeless that it is cruel to permit any such idea to take hold of the American public. Neither is it possible for the war to be settled by the act of some hero or superman. It can only be settled by the united efforts of thousands of men, each contributing his bit. Team play in our civil army at home is as essential as in our fighting army abroad.

I venture to suggest that we cannot all occupy desks at Washington, and it is well for us, and for the country, that we cannot. We can, however, put ourselves and our business in such condition as to meet whatever demand is made upon us. Only relatively few can be useful in the direct service of the army and navy, but there is plenty of honorable work and useful work for us to do. The most effective work for most of us will be in the shops and offices at home, and everyone who does his work loyally and well, is as much a factor in our organized war as the man at the front.

Now, properly understood, the fact that no single great invention is likely to be made which will win the war, is no cause for discouragement. It does not mean that there will be no improvement, no new inventions, no new methods devised and put into effect. It simply means that we must not wait for the miracle which will never appear, but get to work and energetically take advantage of all present knowledge. We must survey the field, get at all the facts, carefully determine our plans and then proceed to put them into practical execution.

Take for example the matter of shipping. This perhaps presents the greatest immediate problem of the war, frightfully complicated as it is by the submarine. I feel sure that it can be successfully solved, if we are content to solve it by the simple, common-sense methods used by engineers and successful business men in the ordinary course of business. The problem must first be carefully investigated, all available data quickly ob-

Digitized by Google

tained and checked, and all new conditions considered, after which a broad-gaged well considered plan, or plans, can be formulated, criticised and then put into effect.

Of course it is elementary to say that we must provide shipping in enormous quantities to replace that destroyed and to provide for increased demands. It is evident that time is the essence of the problem. We must, therefore, build the greatest tonnage in the shortest time. The ships must be manned and navigated to their destination and the most efficient methods provided for docking, unloading and loading.

With the situation such that the race is between ship building and ship destruction, with the destruction many laps ahead, it is vitally important that ships should be loaded and unloaded with the utmost expedition. We have recently heard of an instance where a large ship, after running the gauntlet of a voyage to England, was forced to visit several different ports, and waste one month's time, before starting the return voyage. This loss of time is equal to the loss of a complete voyage. The net tonnage delivered per month is the only thing that counts, therefore ship-tons saved are worth more than ship-tons built. Quick methods of loading and unloading at specially devised terminals, here and in Europe, should be developed and put into operation. The methods are known. It simply remains for us to organize and apply them.

We must see to it that the kind of ships, in respect to size, material and speeds, are such that the greatest tonnage may be moved across the seas in the shortest time. In the time element must of course be considered the time required to build such tonnage. If an investigation should indicate that cargo ships can be built which will successfully withstand one or more torpedo attacks, and which can also be provided with speed and armament sufficient to give them a good chance of fighting off and getting away from a submarine, they should be built no matter whether such ships cost more, or are less adapted for use after the war, or take a little longer time to construct than those of the ordinary type.

It is entirely within the range of possibility that such ships may prove to be the only ones which will be able to navigate the seas with any decent chance of surviving. It would seem clear that, unless the submarine is swept from the seas, it is hopeless to build a large tonnage of slow moving, relatively small and inadequately defended ships, as the net tonnage which

Digitized by Google

could be delivered by such a fleet of ships will be too insignificant to be of any material value. We would have bet on the wrong horse and lost; therefore, I hope that we will have the foresight to build as large a number as possible of big, comparatively torpedo-proof cargo ships, as soon as possible.

We should also, at the same time, consider whether it is worth our while to continue building large dreadnoughts, battle-cruisers, and the like, which cannot possibly be finished for years to come. Our ship building facilities are limited, and if the facilities now devoted to the construction of dreadnoughts could be immediately diverted to the construction of large fairly indestructible, high-speed cargo ships, which can be built in half the time, we would be taking a great step towards solving the problem.

So much for what might be termed the "defensive method" of attacking the problem. Along with this defensive plan, we should put into execution every practical offensive plan of attacking the submarine, such as methods of detection when submerged, methods of attack by means of destroyers, mines, aeroplanes and special artillery. All such methods should be, and probably are being developed, and while no one of them will prove to be the panacea by itself, collectively they will be of the greatest value in reducing the menace. However, I think it is well to emphasize the fact that the only safe and sane plan of action is to assume that we can only win by pushing the development of all practical looking methods of attack and defense, at the same time, and to the limit of our ability.

Now I am well aware that there is nothing theatrical or startling, or novel, in the above suggested solution. For this reason it is not likely to appeal to the great non-technical public, but there is no doubt in my own mind that it represents the scientific and common-sense method, and that if followed with patience, persistence, vigor and diligence, it will prove successful, and if successful, the war cannot be lost. All the other problems of the war—the aeroplane, army, navy, food, manufacturing, farming, transportation, etc.—can be successfully solved by the same scientific, but simple and common-sense methods.

It is a great satisfaction to notice that this country has at last awakened to the importance of developing that great American invention—the aeroplane, and of manufacturing it on a great scale. We should do everything to help accelerate this work. If we can get aeroplanes of the right kind to Europe,

Digitized by Google

soon enough and in sufficient quantities, experts tell us that it will do more to win the war than a large army.

We must also not neglect the development of the submarine, because if we fail to find a way to drive the submarine from the seas in short order, and fail to make relatively unsinkable and uncatchable ships, we may have to rely on big freight submarines, properly convoyed by fighting submarines, if necessary, in order to get food, material and soldiers to Europe.

We must not forget that, after all, all these things must be done by men collectively and that, therefore, it is essential for us to think and act collectively, and with reasonable unanimity. We must co-operate and not nullify our power by quarrels among ourselves. This means that we must be willing to give consideration to the views of others, be ready to make reasonable compromises and be constantly actuated by a spirit of conciliation. We must make every effort to get men of great experience, industry and sound common-sense in positions of trust and influence. We can then hope to have the helpful suggestions offered by other men of experience and wisdom given intelligent and proper consideration. We must give our chosen leaders reasonable time to make and carry into execution their large plans. We must get behind our leaders and loyally support them, and if after a long and fair trial, we find that we have made a mistake in our selection, we should then promptly replace such leaders by those more competent who will surely be found. This is the only way in which a democracy can work and form an effective and efficient organization.

I think I have said enough to indicate that there is plenty of work ahead for engineers at home, as well as abroad; in civil life, as well as camp life. Engineers have a great opportunity in this war and a heavy responsibility. You have special knowledge, experience and a forward looking point of view which the country needs, and it is your duty to see to it that you are given the opportunity to make effective use of your talents, in the service of the Nation, and if you are not given that chance, you must persistently demand it until you get it, and then I feel certain that the victory will be on our side, our civilization will be saved, and the world will be made a safe place for all decent people who will then be able to turn again to the satisfaction and joy of a useful and peaceful existence.

Digitized by Google

Presented by publication only.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

TRANSMISSION LINE DESIGN

BY F. K. KIRSTEN

ABSTRACT OF PAPER

This paper contains a complete mathematical analysis of the forces which determine the location in space of a cable suspended from points of equal elevation, and gives the designer and constructing engineer of a transmission line some useful working formulas based on this analysis.

Section A of the paper covers the derivation of the catenary formulas and contains a chart from which any catenary problem may be quickly and accurately solved.

Section B contains an analysis of the influences of changes in temperature and cable load, resulting in formulas by the aid of which the magnitude of these influences in regard to changes in position of the cable and changes in stresses at any point of the cable may be accurately computed. The formulas derived make it possible to plot a temperature-tension stringing chart to be used by the constructing engineer when stringing the cable at various temperatures.

Section C is an investigation of the economic features involved in the proper design of the cable supports. A working formula is derived enabling the designer to determine the most economical span and corresponding height of tower.

Solutions of typical design problems are given in each section of the paper demonstrating the use and manipulation of all formulas derived.

THE SPAN BETWEEN POINTS OF EQUAL ELEVATION

(*A*). MATHEMATICAL ANALYSIS OF THE PREREQUISITES FOR EQUILIBRIUM OF FORCES ACTING ON A FLEXIBLE CABLE ONLY SUPPORTED AT TWO POINTS OF THE SAME ELEVATION

The curve $P_1 O P_2$ in Fig. 1 represents a cable suspended from points P_1 and P_2 of equal elevation.

Assumptions:

1. The suspended cable is a cylindrical solid with all elements of outer surface parallel.

2. The suspended cable is of uniform texture.

3. The suspended cable is perfectly flexible, that is, the internal forces acting on every element of any cross-sectional plane normal to these forces are equal in magnitude and their lines of action parallel to the axis of the cable.

NOTE: Written discussion of this paper is invited.

Digitized by Google

4. No other external force besides the force of gravitation to be the active force on the cable.

5. The axis of the cable will assume the form of a curve $P_1 O P_2$ in a vertical plane.

Since the active gravitational forces are proportional to mass which is uniformly distributed along the axis of the cable, and since the two points of support are on equal elevation, there must exist a condition of symmetry of the shape of the curve $P_1 O P_2$ with respect to a vertical plane midway between points P_1 and P_2 perpendicular to the straight line $P_1 P_2$. This plane will be selected as the reference plane Y-Y. The point of maximum deflection of the cable from the straight line $P_1 P_2$ must lie in this plane. A horizontal plane tangent to the curve $P_1 O P_2$ at the point of maximum deflection is chosen as the

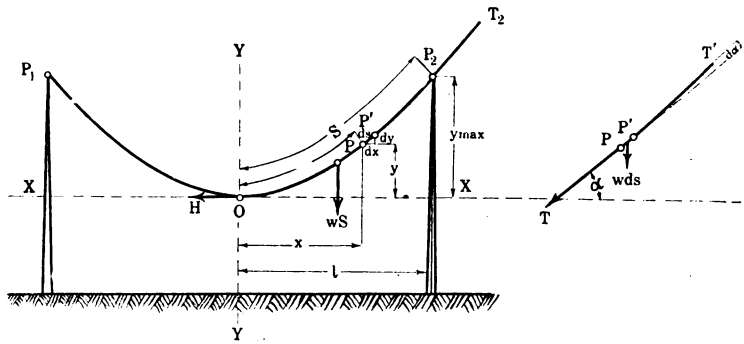


FIG. 1

reference plane X-X. Thus, the point of maximum deflection of the cable is defined as the origin for the rectangular coordinates x and y.

Definitions with reference to Fig. 1

l = half distance between points P_1 and P_2 or half tower spacing.

S = half length of suspended cable or half length of span.

w = weight per unit length of suspended cable

x and y are rectangular coordinates of any point P on the axis of the cable.

s = length of curve between points O and P

ds, dx and dy are increments of s, x and y respectively, which at the limit zero will bear the relation $(dx)^2 + (dy)^2 = (ds)^2$.

Digitized by Google

H = tension on cable at point of maximum deflection.
T_2 = tension on cable at point of support P_2.
T = tension on cable at point P, coordinates x and y.
T' = tension on cable at point P', coordinates $x + dx$ and $y + dy$.
α = angle between T and the X axis.
$d\alpha$ = increment of α or angle between T and T'.

All stresses normal to the cross-sectional plane at any point of the cable are considered as concentrated on the axis of the cable and by assumption 3 act in the direction of the tangent to the axis at that point.

Investigation

For equilibrium of half span (see Fig. 1).

$$T_2^2 = H^2 + w^2 S^2$$

If the point of support were moved to P without disturbing equilibrium,

$$T^2 = H^2 + w^2 s^2 \tag{1}$$

For equilibrium of length ds between points P and P' (see Fig. 1),

$$T \cos \alpha = T' \cos (\alpha + d\alpha) \tag{2}$$

$$T \sin \alpha + w\, ds = T' \sin (\alpha + d\alpha) \tag{3}$$

At point P',

$$(T')^2 = H^2 + w^2 (s + ds)^2 \tag{4}$$

From the geometric relation (right angle triangle) of forces given by equations (1) and (4), it is evident that

$$\cos \alpha = \frac{H}{T}\,;\ \sin \alpha = \frac{w\, s}{T}\,;\ \cos (\alpha + d\alpha) = \frac{dx}{ds}\,;$$

$$\sin (\alpha + d\alpha) = \frac{dy}{ds} \tag{5}$$

Substituting (4) and (5) into (2),

$$H = \left[\ H^2 + w^2 (s + ds)^2\ \right]^{\frac{1}{2}} \frac{dx}{ds}$$

Letting $H = wc$, where c is a constant, and simplifying,

$$\frac{dx}{ds} = \frac{c}{[c^2 + (s + ds)^2]^{\frac{1}{2}}}$$

Digitized by Google

But if ds approaches zero as a limit, at this limit $s + ds = s$, therefore,

$$\frac{dx}{ds} = \frac{c}{[c^2 + s^2]^{\frac{1}{2}}}$$

By integration,

$$x = \int_0^s \frac{c\,ds}{[c^2 + s^2]^{\frac{1}{2}}} = c \left[\log_\epsilon (s + [c^2 + s^2]^{\frac{1}{2}}) \right]_0^s$$

$$= c\,[\log_\epsilon(s + [c^2 + s^2]^{\frac{1}{2}}) - \log_\epsilon c]$$

$$= c \log_\epsilon \frac{s + [c^2 + s^2]^{\frac{1}{2}}}{c} \tag{6}$$

Equation (**6**) may be written

$$\epsilon^{\frac{x}{c}} = \frac{s + [c^2 + s^2]^{\frac{1}{2}}}{c}$$

Or,

$$s = \frac{c}{2}\left[\epsilon^{\frac{x}{c}} - \epsilon^{-\frac{x}{c}} \right] \tag{7}$$

$$= c \sinh \frac{x}{c} \tag{8}$$

And for entire half span:

$$S = c \sinh \frac{l}{c}$$

Substituting (**4**) and (**5**) into (**3**),

$$ws + w\,ds = [H^2 + w^2 (s + ds)^2]^{\frac{1}{2}} \frac{dy}{ds}$$

Letting $H = wc$, where c is a constant, and simplifying,

$$\frac{dy}{ds} = \frac{s + ds}{[c^2 + (s + ds)^2]^{\frac{1}{2}}}$$

But if ds approaches zero as a limit, at this limit $s + ds = s$, therefore,

$$\frac{dy}{ds} = \frac{s}{[c^2 + s^2]^{\frac{1}{2}}}$$

Digitized by Google

By integration,

$$y = \int_0^s \frac{s\,ds}{[c^2 + s^2]^{\frac{1}{2}}} = \left[(c^2 + s^2)^{\frac{1}{2}} \right]_0^s$$
$$= [c^2 + s^2]^{\frac{1}{2}} - c \qquad (9)$$

Substituting (**7**) into (**9**) and simplifying,

$$y = \frac{c}{2}\left[\epsilon^{\frac{x}{c}} + \epsilon^{-\frac{x}{c}} \right] - c \qquad (10)$$

$$= c\left(\cosh \frac{x}{c} - 1\right) \qquad (11)$$

Equations (**10**) or (**11**) are the equations of the catenary.

From equation (**1**) the tension along the axis of the cable at any point P is

$$T = [H^2 + w^2 s^2]^{\frac{1}{2}}$$
$$= [c^2 w^2 + w^2 s^2]^{\frac{1}{2}}$$

Hence:

$$\frac{T}{w} = [c^2 + s^2]^{\frac{1}{2}}$$

By substitution from equation (**8**),

$$\frac{T}{w} = c \cosh \frac{x}{c} \qquad (12)$$

For maximum deflection of entire span and maximum tension at the point of support of the cable, half the tower spacing l must be substituted for x in equations (**11**) and (**12**), giving:

$$y_{max} = c\left(\cosh \frac{l}{c} - 1\right); \qquad \frac{T_{max.}}{w} = c \cosh \frac{l}{c}$$

For preliminary computations of span characteristics or for computations of the characteristics of relatively short spans when maximum precision is not essential, approximations of the above formulas have found universal use. These approximations are obtained as follows:

Digitized by Google

From Maclaurin's Theorem:

$$\epsilon^{\frac{x}{c}} = 1 + \frac{x}{c} + \frac{x^2}{c^2\,\underline{/2}} + \frac{x^3}{c^3\,\underline{/3}} + \frac{x^4}{c^4\,\underline{/4}} + \cdots\cdots$$

$$\epsilon^{-\frac{x}{c}} = 1 - \frac{x}{c} + \frac{x^2}{c^2\,\underline{/2}} - \frac{x^3}{c^3\,\underline{/3}} + \frac{x^4}{c^4\,\underline{/4}} - \cdots\cdots$$

From the above series:

$$\sinh \frac{x}{c} = \frac{\epsilon^{\frac{x}{c}} - \epsilon^{-\frac{x}{c}}}{2} = \frac{x}{c} + \frac{x^3}{c^3\,\underline{/3}} + \frac{x^5}{c^5\,\underline{/5}} + \frac{x^7}{c^7\,\underline{/7}} + \cdots \quad (13)$$

$$\cosh \frac{x}{c} = \frac{\epsilon^{\frac{x}{c}} + \epsilon^{-\frac{x}{c}}}{2} = 1 + \frac{x^2}{c^2\,\underline{/2}} + \frac{x^4}{c^4\,\underline{/4}} + \frac{x^6}{c^6\,\underline{/6}} + \cdots\cdots \quad (14)$$

Since in practical line design the ratio $x \div c$ is less than unity, the terms $\epsilon^{\frac{x}{c}}$ and $\epsilon^{-\frac{x}{c}}$ form, when expanded, rapidly converging series of which the sum of the first terms may be assumed to represent the sum of all terms in the series with sufficient accuracy.

Substituting the first two terms of (**13**) into (**8**) gives

$$s = x + \frac{x^3}{6\,c^2} \quad (15)$$

Substituting the first two terms of (**14**) into (**11**) gives

$$y = \frac{x^2}{2c} \quad (16)$$

Substituting the first two terms of (**14**) into (**12**) gives

$$\frac{T}{w} = c + \frac{x^2}{2c} = c + y \quad (17)$$

Equation (**16**) is the equation of the parabola.

Digitized by Google

The catenary equation (**10**) in its exponential form may seem very complex as compared with the equation of the parabola (**16**), and for that reason the parabolic forms have found great favor in designs which do not require extreme accuracy. However, the reluctance with which the practical engineer calls to his aid the catenary equations is entirely unwarranted for the reason that the exponential form may be converted into its equivalent expressed in hyperbolic functions by equation (**11**). A person, equally versatile in the use of hyperbolic functions or elementary algebra will undoubtedly make a choice in favor of equations (**8**), (**11**) and (**12**) where every possible variable appears without exponents, rather than choosing equations (**15**), (**16**) and (**17**) where x appears with exponents ranging between one and three. It would be absurd to use cumbersome equations resulting in approximations of actual conditions, if relatively simpler forms are available which yield correct results.

In the following analysis the catenary equations will be used exclusively.

Summary

The length of cable suspended between the point of maximum deflection and any point of support P is, by equation (**8**)

$$s = c \sinh \frac{x}{c}$$

The maximum deflection of a suspended cable measured with reference to the elevation of any point of support P is, by equation (**11**)

$$y = c \left(\cosh \frac{x}{c} - 1 \right)$$

The tension per w units weight of unit length of cable acting along the axis of the cable at any point of support P is, by equation (**12**)

$$\frac{T}{w} = c \cosh \frac{x}{c}$$

In the above three equations

x = projection upon a horizontal plane of the distance between the point of maximum deflection and point P.

Digitized by Google

c = length of cable upon which gravitation acts with a force equal to the tension H at the point of maximum deflection.

T = tension at point of support P } expressed in the same
w = weight per unit length of cable } unit.

x, y, s and c are all expressed in the same linear unit, which must also be the same as that used in connection with w.

Solution of Problems. These last three equations show the

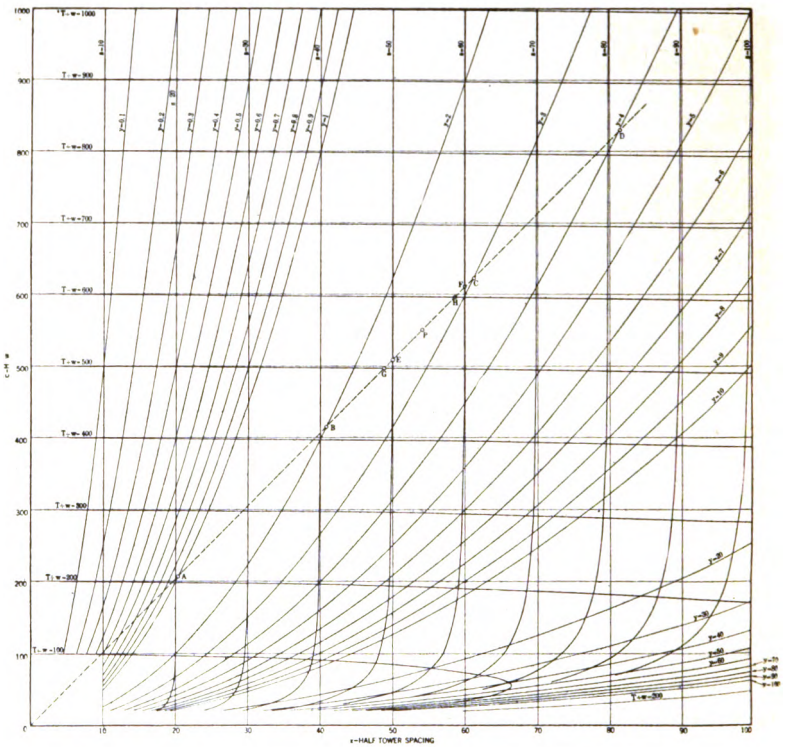


CHART I

concepts s, y and $T \div w$ to be hyperbolic functions of x and c so that their magnitudes could be computed directly if both x and c were the given quantities in a problem of span design. Usually, however, c is not given since it is in reality a more or less fictitious concept and the solution of span problems, with any two of the remaining concepts given, is accomplished by trial methods.

In order to avoid the loss of time incurred by such methods,

Digitized by Google

Chart I has been devised from which, with any two of the five concepts given, the remaining three may be found at once. The chart is laid out on the basis of the decimal system to permit of easy interpolation. The concepts x and c, which form the hyperbolic argument, are the abscissas and ordinates, respectively, of the s, y and $T \div w$ curves.

Interpolation on Chart I. It can be easily demonstrated that any straight line passing through the origin (point O) must be divided into intercepts of equal length by a set of hyperbolic curves the indices of which vary in arithmetic progression. For instance, the curves indexed $y=0.1$, $y = 0.2$, $y = 0.3 \ldots y = 0.9$, $y = 1.0$ have indices which increase progressively by 0.1, and

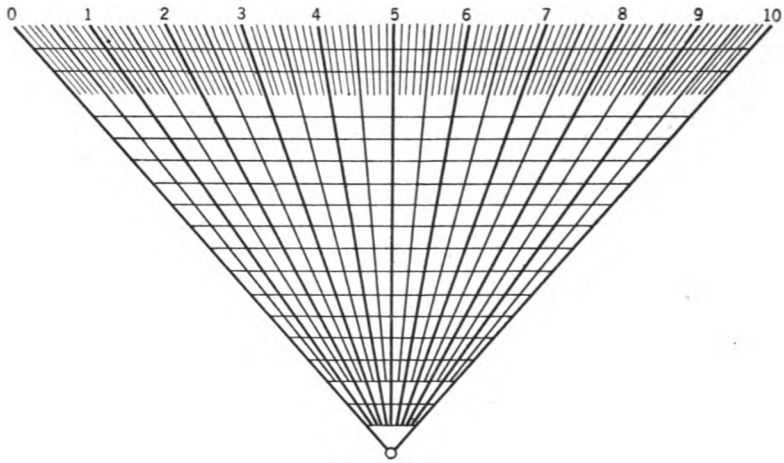


FIG 2

in consequence any straight line passing through the origin will be divided by these ten curves into ten equal intercepts. It follows, then, that if each intercept of this straight line were again divided into ten equal lengths, the division points would be points on the curves $y=0.01$, $y = 0.02$, $y = 0.03 \ldots y = 0.99$, $y = 1.00$. The same reasoning holds true for interpolation between the curves $y = 1$, $y = 2$, $y = 3$, $y = 4, \ldots y = 9$, $y = 10$, and of the last set $y = 10$, $y = 20$, $y = 30$, $y = 40$, $\ldots . y = 90$, $y = 100$. Similarly this system of interpolation is correct for the s and $T \div w$ curves.

In order to be able to accomplish quick and accurate decimal subdivision of any length of line, it is suggested to trace Fig. 2 on transparent cloth or paper for use on Chart I. Any one of

Digitized by Google

the parallel lines in Fig. 2 is divided into ten or a multiple of ten units of equal length.

Example of Interpolation. It is desired to interpolate for s, y and $T \div w$ a point P, coordinates $c = 550$, $x = 54$.

Through point P draw a straight line to the origin O. That this line $P\,O$ is actually subdivided into equal sections by the curves indexed in arithmetic progression is most clearly shown by the intercepts between the y curves. The intercepts $O\,A$, $A\,B$, $B\,C$ and $C\,D$ of the straight line formed by the curves $y = 1$, $y = 2$, $y = 3$ and $y = 4$ are exactly equal in length. The same holds true of the intercepts formed by the s and $T \div w$ curves.

By placing Fig. 2 on the chart so that the two outside radiating lines pass through points E and F and the parallel lines are at the same time parallel to line $E\,F$, point P is interpolated directly and corresponds to the magnitude $s = 54.1$.

Placing Fig. 2 so that the two outside radiating lines pass through points G and H and the parallel lines are parallel to $G\,H$, $T \div w$ is read directly to be 553.

In a similar manner y is read directly to be 2.65.

Chart I is independent of any fixed conventional unit of length, weight or force and may be used with equal precision for the English system of foot-pounds or the decimal system of centimeter-grams.

The use of the chart will now be demonstrated by the solution of two representative problems.

Problem 1. A number of 40-ft. (12.1 m.) poles are to be used for supports of a line consisting of No. 00 hard-drawn, bare copper wires. The points of support on the insulators are 30 ft. (9.1 m.) above the ground level when the poles are installed. The minimum clearance of the wire to the ground is to be 20 ft. (6.0 m.), and the tension on the wire at the point of support is not to exceed 200 lb. 90.7 kg.).

What is the maximum permissible spacing of poles?

The weight per 1000 ft. (304.8 m.), of wire is 402.8 lb. (182.6 kg.). If the pound is chosen as the unit of force and the foot as the unit of length, $w = 402.8 \div 1000 = 0.4028$ and $T \div w = 200 \div 0.4028 = 496.5$; $y = 30 - 20 = 10$.

By interpolation between curves $T \div w = 400$ and $T \div w = 500$ curve $T \div w = 496.5$ is drawn. The intersection point of this curve and the curve $y = 10$ has the abscissa $x = 98.3$, which is half the pole spacing in feet.

Digitized by Google

Hence the maximum permissible pole spacing is $2 \times 98.3 = 196.6$ ft. (59.9 m.).

Problem 2. A $1\frac{1}{2}$-in. (38.1 mm.) steel cable is to span a river. The foundations for the anchor towers on both shores are 10 ft. (3.0 m.) above the water level and a distance of 2000 ft. (609.9 m.) apart. The maximum tension on the cable is not to exceed 70,000 lb. (31,751.4 kg.). Weight of cable is 4700 lb. 2131.8 kg.) per 1000 ft. Clearance between cable and water surface is not to be less than 50 ft. (15.2 m.).

What is the minimum height of anchor towers?

What is the length of cable between points of support?

What are the vertical and horizontal components of the tension on the points of support in the plane of the suspended cable?

Half the tower spacing is 1000 ft. In order to bring this value within range of Chart I, the unit of length will be chosen as 20 ft. Hence $x = 1000 \div 20 = 50$. For the same unit of length $w = 4700 \times 20 \div 1000 = 94$. Therefore $T \div w = 70{,}000 \div 94 = 745$. This value is within range of the chart. If this value had exceeded the range of the chart, the unit of length would have to be taken greater than 20 ft.

Between the curves $T \div w = 700$ and $T \div w = 800$ a short length of curve $T \div w = 745$ is interpolated near the line $x = 50$. The point of intersection of this curve with the line $x = 50$ has the ordinate $c = 742$. Now a straight line is drawn from the origin through point $x = 50$, $c = 742$ and this point interpolated on the straight line for y and for s.

Interpolation between curves $y = 1$ and $y = 2$ yields $y = 1.68$. Interpolation between $s = 50$ and $s = 60$ yields $s = 50.1$. Hence,

Maximum deflection $= y = 1.68$ units $= 33.6$ ft. (10.2 m.)

Length of cable $= 2s = 2 \times 50.1$ units $= 2004$ ft. (610.8 m.).

Minimum height of anchor tower $= 33.6 + 50 - 10 = 73.6$ ft. (22.4 m.).

Vertical component of tension on point of support $= 2004 \div 2 \times 4.7 = 4720$ lb. (2140.9 kg.)

Horizontal component of tension on point of support in plane of cable $= c\,w = 742 \times 20 \times 4.7 = 69{,}748$ lb. (31,637 kg.).

Average Tension on Cable Between Points of Support

The tension at any point P from equation (**1**) is

$$T = [H^2 + w^2 s^2]^{\frac{1}{2}}$$

$$= w\,[c^2 + s^2]^{\frac{1}{2}}$$

Digitized by Google

For the average tension along the axis of the cable the above expression for the tension at any point must be integrated between the limits 0 and s and the result divided by s. Hence; the average tension is

$$\text{av. } T = \frac{w}{s}\int_0^s [c^2 + s^2]^{\frac{1}{2}}\, ds$$

$$= \frac{w}{s}\left[\frac{s}{2}[c^2 + s^2]^{\frac{1}{2}} + \frac{c^2}{2}\log_\epsilon (s + [c^2 + s^2]^{\frac{1}{2}})\right]_0^s$$

$$= \frac{w}{s}\left[\frac{s}{2}[c^2 + s^2]^{\frac{1}{2}} + \frac{c^2}{2}\log_\epsilon (s+[c^2+s^2]^{\frac{1}{2}}) - \frac{c^2}{2}\log_\epsilon c\right]$$

$$= \frac{w}{s}\left(\frac{s}{2}[c^2 + s^2]^{\frac{1}{2}} + \frac{c^2}{2}\log_\epsilon \frac{s + [c^2 + s^2]^{\frac{1}{2}}}{c}\right) \qquad (18)$$

But by substitutions from equations (**6**) and (**9**), (**18**) becomes:

$$\text{av. } T = \frac{w}{2}\left[y + c + \frac{cx}{s}\right]$$

But from (**8**),

$$s = c \sinh \frac{x}{c}$$

and from (**11**),

$$y = c\left(\cosh \frac{x}{c} - 1\right)$$

Therefore,

$$\text{av. } T = \frac{w}{2}\left[c \cosh \frac{x}{c} + \frac{x}{\sinh \frac{x}{c}}\right]$$

$$= \frac{cw}{2}\left[\cosh \frac{x}{c} + \frac{\frac{x}{c}}{\sinh \frac{x}{c}}\right] \qquad (19)$$

Digitized by Google

or,

$$\frac{\text{av. } T}{w} = \frac{c}{2}\left[\cosh\frac{x}{c} + \frac{\frac{x}{c}}{\sinh\frac{x}{c}}\right] \qquad (20)$$

Here it is shown again that the ratio of the average tension on a suspended cable to its weight per unit length is a hyperbolic function of x and c.

Attention is here called to the similarity of equations (**12**) and (**20**). For all positive magnitudes x and c,

$$c < \frac{c}{2}\left[\cosh\frac{x}{c} + \frac{\frac{x}{c}}{\sinh\frac{x}{c}}\right] < c\cosh\frac{x}{c}$$

However, the smaller the value x, the more equal will be the above expressions until

$$\underset{x\,=\,o}{\text{limit}}\left\{c = \frac{c}{2}\left[\cosh\frac{x}{c} + \frac{\frac{x}{c}}{\sinh\frac{x}{c}}\right] = c\cosh\frac{x}{c}\right.$$

At this limit, then

$$cw = \text{av. } T = T$$

But $cw = H$ = tension at the point of maximum deflection.

A very close approximation to formula (**19**) is obtained by using the average between the tension at the point of support and the tension at the point of maximum deflection:

$$\frac{cw\cosh\frac{x}{c} + cw}{2} = \frac{cw}{2}\left[\cosh\frac{x}{c} + 1\right]$$

(*B*). Effect of Changes in Temperature on the Catenary Described by a Cable Suspended Between Two Fixed Points of the Same Elevation

In the preceding investigation the concept w (weight per unit length of cable) has been treated as a constant for a given cable.

Digitized by Google

Since, however, w is a function, not only of the material composition of the cable, but also a function of the temperature of the cable and the tension acting on it, the same cable suspended from two fixed points may describe as many different catenaries as there are different possible magnitudes of w.

In practical engineering the cable is strung at a given tension and permanently fastened at the points of support. This fixes, once for all, the amount of mass of cable between the two points. How this mass arranges itself in space under conditions different from those existing at the time of stringing will be shown in the following investigation.

Influence of Changes in Temperature. Within a certain range of temperature a given unit length of cable will change its three dimensions practically in direct proportion to the magnitude of the temperature change. This range more than covers the most extreme weather conditions recorded, and in consequence the designer of practical spans may use the formula

$$s_t = s_0 (1 + \alpha [t - t_0]) \tag{21}$$

where

s_0 = length of cable at any given initial temperature.
s_t = length of cable at final temperature.
t_0 = initial temperature.
t = final temperature
α = coefficient of expansion, characteristic of the material composition of the cable.

Not only the length of the cable but also its cross-sectional area changes in accordance with the same law, so that

$$A_t = A_0 (1 + \alpha [t - t_0])^2 \tag{22}$$

where

A_0 = cross-sectional area of cable at initial temperature.
A = cross-sectional area of cable after the temperature has changed $t - t_0$ degrees.

The total mass of a cable suspended between two fixed points is constant and independent of temperature, whereas the length of the cable changes with the temperature. Therefore, the weight per unit length of the cable must change in inverse proportion to the length of the cable, that is,

$$\frac{s_0}{s_t} = \frac{w_t}{w_0} \tag{23}$$

Digitized by Google

where

w_0 = weight per unit length of cable at initial temperature.
w_t = weight per unit length of cable after the temperature has changed $t - t_0$ degrees.

Influence of Change in Tension. If the tension at any point of the catenary were proportional to the product of s and w, a change in temperature would not affect this tension, but according to equation (**12**)

$$T = wc \cosh \frac{x}{c}$$

whereas, according to (**8**)

$$s = c \sinh \frac{x}{c}$$

Hence, a change in length of cable caused by a change in temperature is accompanied by a change in tension at every point of the catenary. However, the condition

$$T = wc \cosh \frac{x}{c}$$

is always realized during each minute step in this change, the only constant in the equation being x, while all other terms change according to definite laws.

Within a certain range of stresses, the limits of which the stresses in a well designed line should not exceed, the strain of the cable is practically proportional to the stress. This characteristic of the cable is described by the formula

$$s_1 = s_0 \left(1 + \frac{T - T_0}{EA}\right) \qquad (\mathbf{24})$$

where

s_0 = length of cable under initial tension.
s_T = length of cable under final tension.
T_0 = initial tension.
T = final tension.
A = cross-sectional area of cable.
E = modulus of elasticity, characteristic of the material composition of the cable.

Digitized by Google

The above formula, however, does not take into account the change in cross-sectional area of the cable with the change in tension from T_0 to T. Since at constant temperature the volume of the cable remains constant, an increase or decrease in length, caused by a change in tension on the cable, is accompanied by a proportional decrease or increase, respectively, of the cross-sectional area of the cable. The concept A should be understood to represent the average cross-sectional area of the cable as its length changes from T_0 to T. Or, if

A_0 = cross-sectional area of cable under initial tension,
A_T = cross-sectional area of cable under final tension,

$$A = \frac{A_0 + A_T}{2}$$

Equation (**24**) would then become

$$s_T = s_0 \left(1 + \frac{2\,[T - T_0]}{E\,[A_0 + A_T]}\right) \tag{25}$$

In order to simplify equation (**25**) for future use, an approximation

$$s_T = s_0 \left(1 + \frac{T}{EA_T} - \frac{T_0}{EA_0}\right) \tag{26}$$

will be substituted which is more accurate than equation (**24**), but which does not describe conditions quite as precisely as (**25**).

If the strain is proportional to the stress, the total change in the length of a suspended cable is proportional to the change in average tension along the cable, or

$$s_T = s_0 \left[1 - \frac{\text{av.}\,T_0}{EA_0} + \frac{\text{av.}\,T}{EA_T}\right) \tag{27}$$

where

av. T_0 = initial average tension.
av. T = final average tension.

The relation

$$s_0 A_0 = s_T A_T \tag{28}$$

expresses the constancy of volume of the cable subjected to different tensions av. T_0 and av. T.

Digitized by Google

Although a change in tension produces a deformation of the cable, its total mass remains the same and, in consequence its weight per unit length must change in inverse proportion to the length of the cable, that is,

$$\frac{s_0}{s_T} = \frac{w_T}{w_0} \tag{29}$$

where

w_0 = weight per unit length of cable under av. T_0.
w_T = weight per unit length of cable under av. T.

Influence of Ice and Wind Loading. Usually the gravitational forces acting on a suspended cable by virtue of its mass are augmented by a layer of ice on the cable at low temperatures and by the action of wind on the cable at all temperatures. The ice loading simply increases w which is a vertical downward force, whereas the wind pressure acts horizontally deflecting the cable from its position in a vertical plane to another position in a plane inclined to the vertical at an angle whose tangent is

$$\frac{p}{w + i}$$

where

i = weight of ice per unit length of cable.
p = wind pressure exerted on unit length cable with ice coating.

} expressed in the same unit.

The resultant force per unit length of the cable acting downward in the deflected plane is

$$w_1 = [(w + i)^2 + p^2]^{\frac{1}{2}} \tag{30}$$

or the catenary described by the cable in an inclined plane under the influence of ice and wind loading is equivalent to a catenary described in a vertical plane by a cable whose weight per unit length is w_1.

With the knowledge of the influences which may act on a suspended cable in all climatic conditions, and with the knowledge of the laws which govern the response of the suspended cable to these influences, all possible catenaries described by the cable can be mathematically expressed.

Let it be required to find all possible catenaries that can be described by a cable, the characteristics of which are specified by the manufacturer as follows:

Digitized by Google

Weight per unit length free from stress $= w$ } measured at
Cross-sectional area free from stress..... $= A$ } temperature t
Modulus of elasticity..... $= E$
Coefficient of expansion..... $= \alpha$
Maximum safe stress on cable..... $= T_{max}$

Investigation of the records, furnished by the weather bureau located near the place where the cable is to be suspended, shows:

Minimum observed temperature.... $= t_1$
Maximum observed temperature.... $= t_4$
Maximum observed wind pressure.. $= v$ units per unit area normal to direction of wind.

I. Catenary Covering Conditions at Minimum Temperature; Cable Under Ice Loading and Wind Pressure

Note: All concepts characteristic of conditions specified in the heading of this section will appear with the subscript 1.

The maximum stress acts on the cable at the point of support, when the temperature is a minimum, and when at the same time the cable carries its maximum ice and wind load. From equation (**12**) this maximum stress is

$$\max T_1 = w_1 c_1 \cosh \frac{x}{c_1} \tag{31}$$

The magnitude max T_1 in equation (**31**) is given in the specifications and the equation could be solved for any argument $x \div c_1$ if w_1 were known. The magnitude of w_1, is determined as follows:

Due to a change in temperature from t to t_1, w changes according to equations (**21**) and (**23**) to

$$w' = \frac{w}{1 - \alpha [t - t_1]} \tag{32}$$

At the same time the cross-sectional area A changes according to equation (**22**) to

$$A' = A (1 - \alpha [t - t_1])^2 \tag{33}$$

Now let it be assumed that the cable receives its ice loading and is strung under a wind pressure v so that the tension at the point of support is maxT_1. On account of this tension the weight

Digitized by Google

per unit length again changes according to equations (**27**) and (**29**) to

$$w'' = \frac{w'}{1 + \frac{\text{av.}\, T_1}{EA_1}} \tag{34}$$

where

av. T_1 = average tension along span corresponding to max T_1 at point of support.

In order to simplify computations for w'' the ratio max $T_1 \div EA'$ will be substituted for the ratio av. $T_1 \div EA_1$ in equation (**34**). max T_1 and A' are both slightly greater than av. T_1 and A_1, respectively, however, their ratios are practically identical. In the case of very long spans this approximation would slightly increase the factor of safety for cable stress, which is a desirable feature. Equation (**34**) is changed to

$$w'' = \frac{w'}{1 + \frac{\max T_1}{EA'}} \tag{35}$$

From equations (**28**) and (**29**)

$$A_1 = \frac{w'' A'}{w'} \tag{36}$$

Let the thickness of the layer of ice be a all around the cable, then the volume of ice per unit length of cable is

$$\frac{\pi}{4}\left(2\left[\frac{A_1}{\pi}\right]^{\frac{1}{2}} + 2a\right)^2 - A_1 = \pi a\left(a + 2\left[\frac{A_1}{\pi}\right]^{\frac{1}{2}}\right)$$

and the weight of ice per unit length of cable is

$$i = u\pi a\left(a + 2\left[\frac{A_1}{\pi}\right]^{\frac{1}{2}}\right) \tag{37}$$

where

u = weight per unit volume of ice.

The maximum force exerted by the wind on unit length of cable with ice envelope is

$$p = 2v\left(a + \left[\frac{A_1}{\pi}\right]^{\frac{1}{2}}\right) \tag{38}$$

Digitized by Google

With a given wind velocity the wind pressure acting on a cylindrical body of unit length is here assumed to be the same as the wind pressure acting on a rectangular plane of unit length and of width equal to the diameter of the cylindrical body, provided that the inclination to the direction of the wind of the axis of the cylinder is the same as that of the plane of the rectangular surface. The result of the slight error in this assumption is an increase in the factor of safety for cable stress.

The resultant, equivalent weight per unit length of catenary in an inclined plane is, according to equation (**30**)

$$w_1 = [(w'' + i)^2 + p^2]^{\frac{1}{2}} \tag{39}$$

where, from equations (**32**), (**33**) and (**35**),

$$w'' = \frac{w\,E\,A\,(1 - \alpha\,[t - t_1])}{E\,A\,(1 - \alpha\,[t - t_1])^2 + \max T_1} \tag{40}$$

and from equations (**33**), (**35**), (**36**) and (**37**),

$$i = u\,\pi\,a\left[a + 2A\,(1 - \alpha\,[t - t_1])^2 \left(\frac{E}{\pi\,[E\,A\,(1 - \alpha\,[t - t_1])^2 + \max T_1]}\right)^{\frac{1}{2}}\right] \tag{41}$$

and similarly:

$$p = 2v\left[a + A\,(1 - \alpha\,[t - t_1])^2 \left(\frac{E}{\pi\,[E\,A\,(1 - \alpha\,[t - t_1])^2 + \max T_1]}\right)^{\frac{1}{2}}\right] \tag{42}$$

The actual average cross-sectional area of the cable, not including ice covering, is from equations (**33**), (**35**) and (**36**),

$$A_1 = \frac{E\,A^2\,(1 - \alpha\,[t - t_1])^4}{E\,A\,(1 - \alpha\,[t - t_1])^2 + \max T_1} \tag{43}$$

Equation (**31**) can now be solved for any argument $x \div c_1$ since max T_1 and w_1 are given in terms of the manufacturer's specification and in terms of the minimum temperature and maximum wind pressure.

Digitized by Google

Equations (**41**) and (**42**) seem rather elaborate in view of the arbitrary assumption of the thickness of the ice envelope, but for the sake of accurate comparisons between the characteristics of cables of different size or material, exactly the same assumptions, however arbitrary they may be, should hold for all cables to be compared. So, if it is not a question as to what kind of a cable to use for certain span requirements, the application of approximations which greatly simplify equations (**41**) and (**42**) is justified. The substitution of A for A_1 in these two equations would yield a permissible approximation in the form of the simplest expressions for i and p.

From equation (**8**)

$$s_1 = c_1 \sinh \frac{x}{c_1} \tag{44}$$

and from equation (**11**)

$$y_1 = c_1 \left(\cosh \frac{x}{c_1} - 1 \right) \tag{45}$$

Equations (**31**), (**44**) and (**45**) completely describe the catenary for minimum temperature with wind and ice loading.

II. Catenaries Covering Conditions From Minimum Temperature to the Freezing Point: Cable Under Ice Loading and Wind Pressure

Note: All concepts characteristic of the range of conditions specified in the heading of this section will appear with the subscript **2**.

It is assumed that the total weight of the suspended cable remains constant as the temperature increases from t_1 to the freezing point t_2. At the freezing point it is assumed that no wind is blowing, that, however, on account of the calmness of the atmosphere a greater accumulation of snow on the cable is possible, resulting in the same total weight of the cable. At the freezing point, then, the catenary lies in a vertical plane.

Let the temperature change from t_1 to t_2 without a change in tension and w_1, then, according to equation (**21**), s_1 changes to

$$s_1' = s_1 (1 + \alpha [t_2 - t_1]) \tag{46}$$

and, according to equation (**22**),

$$A_1' = A_1 (1 + \alpha [t_2 - t_1])^2 \tag{47}$$

On account of the change in temperature the average tension at temperature t_1 (av. T_1) changes to the average tension at temp-

Digitized by Google

erature t_2 (av. T_2), and according to equation (**27**) the length s_1' changes to

$$s_2 = s_1' \left(1 - \frac{\text{av. } T_1}{E A_1'} + \frac{\text{av. } T_2}{E A_2}\right) \tag{48}$$

From equation (**8**), at temperature t_2,

$$s_2 = c_2 \sinh \frac{x}{c_2} \tag{49}$$

and the average tension, according to equation (**19**) is

$$\text{av. } T_2 = \frac{c_2 w_2}{2} \left[\cosh \frac{x}{c_2} + \frac{\frac{x}{c_2}}{\sinh \frac{x}{c_2}}\right] \tag{50}$$

At temperature t_1 the average tension was

$$\text{av. } T_1 = \frac{c_1 w_1}{2} \left[\cosh \frac{x}{c_1} + \frac{\frac{x}{c_1}}{\sinh \frac{x}{c_1}}\right] \tag{51}$$

Although the tension has changed from av. T_1 to av. T_2, the volume of the cable remains constant, or,

$$s_1' A_1' = s_2 A_2$$

Hence,

$$A_2 = \frac{s_1' A_1'}{s_2} \tag{52}$$

From the assumption that the total weight of the suspended cable remains constant,

$$s_1 w_1 = s_2 w_2$$

Hence,

$$w_2 = \frac{s_1 w_1}{s_2} \tag{53}$$

Substituting equations (**46**), (**47**), (**49**), (**50**), (**51**), (**52**) and (**53**) into (**48**),

Digitized by Google

$$c_2 \sinh \frac{x}{c_2} =$$

$$s_1(1+\alpha[t_2-t_1])\left(1 - \frac{w_1 c_1}{2 E A_1(1+\alpha[t_2-t_1])^2}\left[\cosh\frac{x}{c_1} + \frac{\frac{x}{c_1}}{\sinh \frac{x}{c_1}}\right]\right.$$

$$\left. + \frac{w_1 c_2}{2 E A_1(1+\alpha[t_2-t_1])^3}\left[\cosh\frac{x}{c_2} + \frac{\frac{x}{c_2}}{\sinh \frac{x}{c_2}}\right]\right)$$

$$= s_1(1+\alpha[t_2-t_1]) - \frac{s_1 w_1 c_1}{2 E A_1(1+\alpha[t_2-t_1])}\left[\cosh\frac{x}{c_1} + \frac{\frac{x}{c_1}}{\sinh \frac{x}{c_1}}\right]$$

$$+ \frac{s_1 w_1 c_2}{2 E A_1(1+\alpha[t_2-t_1])^2}\left[\cosh\frac{x}{c_2} + \frac{\frac{x}{c_2}}{\sinh \frac{x}{c_2}}\right]$$

Dividing both sides of above equation by x:

$$\frac{\sinh \frac{x}{c_2}}{\frac{x}{c_2}} =$$

$$\frac{s_1}{x}(1+\alpha[t_2-t_1]) - \frac{s_1 w_1}{2 E A_1(1+\alpha[t_2-t_1])}\left[\frac{\cosh\frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh \frac{x}{c_1}}\right]$$

$$+ \frac{s_1 w_1}{2 E A_1(1+\alpha[t_2-t_1])^2}\left[\frac{\cosh\frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh \frac{x}{c_2}}\right] \tag{54}$$

By substituting for t_2 in equation (**54**) values ranging between t_1 and the freezing point, any catenary within that range of temperature can be computed, provided that the equivalent weight per unit length of suspended cable remains constant.

Digitized by Google

III. Catenaries Covering Conditions From Minimum Temperature to Maximum Temperature; Cable Not Subjected to Either Wind or Ice Loading

NOTE: All concepts characteristic of the range of conditions specified in the heading of this section will appear with the subscript 3 for the catenary at the minimum temperature and with the subscript 4 for all other catenaries.

It is now assumed that at the minimum temperature t_1 the ice and wind load is removed from the suspended cable, thereby changing the total weight of the span from $w_1 s_1$ to $w_3 s_3$. Under ice and wind loading the total equivalent weight of the cable is $w_1 s_1$, while the total weight of the cable alone is $w'' s_1$ which is the total mass of metal suspended between the points of support. Since the total mass of the cable does not change,

$$s_3 w_3 = s_1 w'' \tag{55}$$

The average tension under ice and wind loading was

$$\text{av. } T_1 = \frac{c_1 w_1}{2}\left[\cosh \frac{x}{c_1} + \frac{\frac{x}{c_1}}{\sinh \frac{x}{c_1}}\right]$$

but has now changed to

$$\text{av. } T_3 = \frac{c_3 w_3}{2}\left[\cosh \frac{x}{c_3} + \frac{\frac{x}{c_3}}{\sinh \frac{x}{c_3}}\right] \tag{56}$$

The change in tension produces a change in length of cable from s_1 to s_3. Expressing this change in length as per equation (27):

$$s_3 = s_1\left(1 - \frac{\text{av. } T_1}{E A_1} + \frac{\text{av. } T_3}{E A_3}\right) \tag{57}$$

From equation(8),

$$s_3 = c_3 \sinh \frac{x}{c_3} \tag{58}$$

Although the cable changes its length, its volume remains constant, or,

$$s_1 A_1 = s_3 A_3 \tag{59}$$

Digitized by Google

Substituting from equations (**51**), (**55**), (**56**), (**58**) and (**59**) into (**57**) and dividing both sides of the equation by x, gives:

$$\frac{\sinh\frac{x}{c_3}}{\frac{x}{c_3}} = \frac{s_1}{x} - \frac{s_1 w_1}{2 E A_1}\left[\frac{\cosh\frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh\frac{x}{c_1}}\right] + \frac{s_1 w''}{2 E A_1}\left[\frac{\cosh\frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh\frac{x}{c_3}}\right]. \tag{60}$$

Equation (**60**) describes the characteristics of the catenary at minimum temperature without either wind or ice loading. All other catenaries for higher temperatures may be found by the use of equation (**54**) which is also based on the assumption that the total weight of the suspended cable is constant irrespective of changes in temperature and tension. Substituting for s_1, w_1, A_1 and c_2 in equation(**54**) the values s_3, w_3, A_3 and c_4, respectively, which are found by the solution of equation (**60**), equation (**54**) changes to

$$\frac{\sinh\frac{x}{c_4}}{\frac{x}{c_4}} = s_3(1+\alpha[t_4-t_1]) - \frac{s_3 w_3}{2 E A_3 (1+\alpha[t_4-t_1])}\left[\frac{\cosh\frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh\frac{x}{c_3}}\right] + \frac{s_3 w_3}{2 E A_3 (1+\alpha[t_4-t_1])^2}\left[\frac{\cosh\frac{x}{c_4}}{\frac{x}{c_4}} + \frac{1}{\sinh\frac{x}{c_4}}\right] \tag{61}$$

According to the reasoning outlined by equations (**52**) and (**53**),

$$\frac{w_3}{A_3} = \frac{w''}{A_1}$$

Digitized by Google

which, if substituted into equation (**61**) simplifies this equation to the form

$$\frac{\sinh \frac{x}{c_4}}{\frac{x}{c_4}} =$$

$$s_3 (1+\alpha [t_4-t_1]) - \frac{s_3 w''}{2 E A_1 (1+\alpha [t_4-t_1])}\left[\frac{\cosh \frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh \frac{x}{c_3}}\right]$$

$$+ \frac{s_3 w''}{2 E A_1 (1+\alpha [t_4-t_1])^2}\left[\frac{\cosh \frac{x}{c_4}}{\frac{x}{c_4}} + \frac{1}{\sinh \frac{x}{c_4}}\right] \tag{62}$$

The concept t_4 covers the range from the minimum to the maximum temperature.

In the design of a practical span the engineer must guarantee, first, that the suspended cable will not break under the influence of the most severe weather conditions recorded in the locality where the span is to be installed and, secondly, that the clearance of the cable from the ground or from a given reference plane will never be less than a given, permissible magnitude; provided that the extremes of the climate recorded for the past of the locality in question are not exceeded in the future.

The first mentioned requirement is met by the use of equation (**31**), if for max.T_1 the maximum safe stress on the cable is substituted and proper allowances are made in the determination of w_1 for ice loading and wind pressure. The guarantee for proper clearance from the ground or from a given reference plane is based upon the knowledge of the maximum deflection of the suspended cable for a given range of climate from extreme winter weather at minimum temperature to the maximum summer heat.

It is evident that the minimum deflection occurs at minimum temperature when the cable is free from ice load and wind pressure. Supposing the cable receives at this temperature a coating of ice being at the same time subjected to wind pressure, which is equivalent to an increase of the gravitational forces acting

Digitized by Google

on the span, equilibrium of forces is re-established by an increase in tension on the cable and its consequent elongation [see equation (**27**)]. Since the distance between the points of support is constant, an increase in length of the cable suspended from these points means an increase in its deflection. Let the temperature increase toward the freezing point. An increase in temperature is accompanied by an increase in length of the cable. Although this increase in length is partly offset by a decrease in tension, as demonstrated in the derivation of equation (**54**), an increase in length does result from an increase in temperature for all materials used in practical transmission spans, and in consequence the deflection of the cable must increase also; provided that the ice coating and wind pressure do not diminish. Since the ice loading cannot exist above the freezing point, the deflection will naturally reach a maximum at the freezing point.

As soon as the temperature rises above the freezing point, the ice load and a large portion of the wind load vanish, resulting in a decrease in the deflection. If the temperature increases to its maximum, the deflection will also increase to a maximum which may either be smaller or greater than the deflection at the freezing point, depending upon the relative magnitude of the maximum temperature and the magnitude of the ice and wind loading which existed at the freezing point. With the help of equation (**54**) the maximum deflection of a given cable for any length of span may be accurately computed for conditions of ice and wind loading at the freezing point. Equations (**60**) and (**62**), solved in sequence, will yield the deflection at the maximum temperature. The one of the two catenaries thus found, which gives the greatest deflection will hereafter be called the *critical catenary*. In warm climates the critical catenary will tend to exist at the maximum temperature, whereas in cold climates the critical catenary is likely to be found at the freezing point. The diameter of the cable is also a factor in the determination of the critical catenary. The smaller the diameter, the greater is the ice load in comparison to the weight of the cable itself, so that at the same locality the critical catenary may occur at the maximum temperature for a large cable, whereas for a smaller cable it might occur at the freezing point. It is at all times advisable to calculate the catenaries for both the maximum temperature and the freezing point in order to be sure of accurate results.

Digitized by Google

At first sight equations (**54**), (**60**) and (**62**) will appear rather cumbersome and difficult to operate. If, however, equation (**54**) is written

$$\frac{\sinh \frac{x}{c_2}}{\frac{x}{c_2}} = F_1 - G_1 + H_1 \left[\frac{\cosh \frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh \frac{x}{c_2}} \right]$$

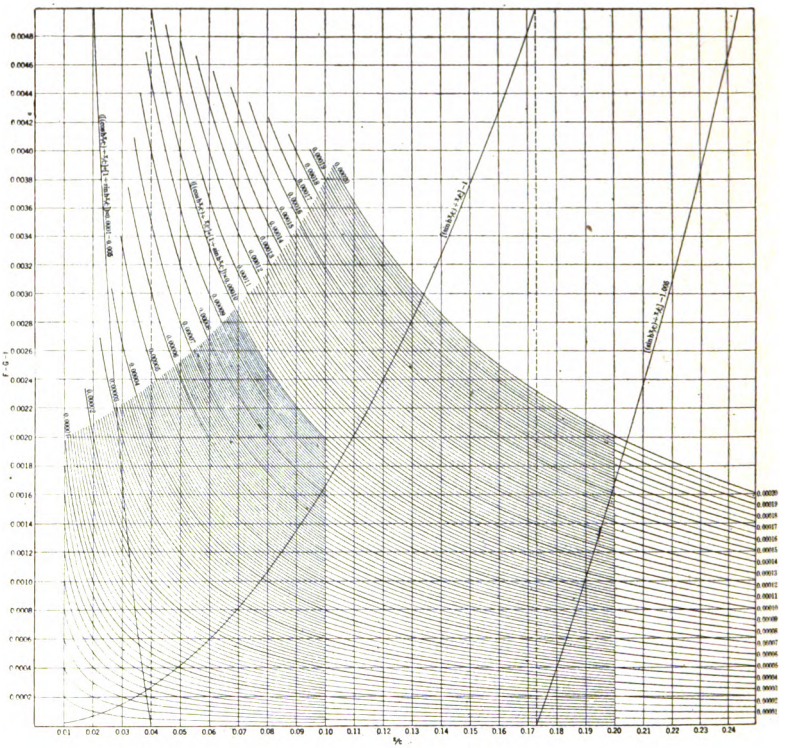


CHART II

where F_1, G_1 and H_1 are constants, the simplicity of the solution of the equation for the argument $x \div c_2$ is apparent.

Equations (**54**), (**60**) and (**62**) are easily and rapidly solved by the use of the curves of Chart II. The curve indexed

$$\left[\left(\sinh \frac{x}{c} \right) \div \frac{x}{c} \right] - 1$$

Digitized by Google

gives values of the magnitude

$$\left[\left(\sinh \frac{x}{c}\right) \div \frac{x}{c}\right] - 1$$

for arguments $x \div c$ ranging from 0 to 0.25. The curve indexed

$$0.0001\left[\frac{\cosh \frac{x}{c}}{\frac{x}{c}} + \frac{1}{\sinh \frac{x}{c}}\right]$$

represents magnitudes of

$$H \times \left[\frac{\cosh \frac{x}{c}}{\frac{x}{c}} + \frac{1}{\sinh \frac{x}{c}}\right]$$

for the same range of the argument, if $H = 0.0001$. Corresponding curves for values of H ranging from 0 to 0.0002 are indexed 0.00001, 0.00002,...0.00019, 0.0002. A straight line perpendicular to the $x \div c$ axis is divided into equal lengths by these curves indexed in arithmetic progression and in consequence direct interpolation can be effected along such lines perpendicular to the $x \div c$ axis.

For all positive arguments the ratio of the hyperbolic sine to the argument is always greater than unity. By subtracting unity from this ratio, the two sets of curves of Chart II are located nearer the $x \div c$ axis. The equation is again balanced by subtracting unity from the constants. Hence, for convenience equation (**54**) is changed in form to

$$\frac{\sinh \frac{x}{c_2}}{\frac{x}{c_2}} - 1 = F_1 - G_1 + H_1 \times \left[\frac{\cosh \frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh \frac{x}{c_2}}\right] - 1$$

Supposing, $F_1 = 1.002821$; $G_1 = 0.000\ 525$; and $H_1 = 0.0000315$, then

$$F_1 - G_1 - 1 = 0.002296.$$

Digitized by Google

The magnitude

$$H_1 \times \left[\frac{\cosh \frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh \frac{x}{c_2}} \right]$$

$$= 0.0000315 \left[\frac{\cosh \frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh \frac{x}{c_2}} \right]'$$

is given by a curve interpolated between curves indexed 0.00003 and 0.00004 for any argument $x \div c_2$ between the limits 0 and 0.25. The value 0.002296 added to an ordinate of this curve must be, according to the above equation, an ordinate of curve

$$\left[\left(\sinh \frac{x}{c_2} \right) \div \frac{x}{c_2} \right] - 1$$

Hence, the correct argument $x \div c_2$ which gives the same length of ordinate for the curves

$$\left[\left(\sinh \frac{x}{c_2} \right) \div \frac{x}{c_2} \right] - 1$$

and

$$0.002296 + 0.0000315 \left[\frac{\cosh \frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh \frac{x}{c_2}} \right]$$ can be found by

marking the length 0.002296 on the straight edge of a sheet of paper and by moving the point marked on the sheet along the curve 0.0000315, keeping the straight edge perpendicular to the $x \div c$ axis, until the other point touches the curve

$$\left[\left(\sinh \frac{x}{c} \right) \div \frac{x}{c} \right] - 1$$

The straight edge in this position indicates on the $x \div c$ axis the value 0.1294, which, if substituted for $x \div c_2$ in above equation will satisfy this equation.

Digitized by Google

The curves of Chart II have been drawn with great care from hyperbolic functions computed accurate to the twelfth decimal place. With a little practise in interpolation the argument of equations (**54**), (**60**) and (**62**) can be determined accurately to the fourth decimal place. Values of

$$0.0001\left[\frac{\cosh\frac{x}{c}}{\frac{x}{c}}+\frac{1}{\sinh\frac{x}{c}}\right]$$

with a given argument can be read directly to the sixth decimal place from the curve bearing this index.

Outline for Systematic Determination of the Critical Catenary

First Step. Determination of the catenary at the freezing point with ice and wind loading, using equation (**54**) changed for convenience to

$$\frac{\sinh\frac{x}{c_2}}{\frac{x}{c_2}}-1=F_1-G_1+H_1\times\left[\frac{\cosh\frac{x}{c_2}}{\frac{x}{c_2}}+\frac{1}{\sinh\frac{x}{c_2}}\right]-1 \qquad (63)$$

where

$$F_1=\frac{s_1}{x}\left(1+\alpha\left[t_2-t_1\right]\right)$$

$$G_1=\frac{s_1 w_1}{2 E A_1\left(1+\alpha\left[t_2-t_1\right]\right)}\left[\frac{\cosh\frac{x}{c_1}}{\frac{x}{c_1}}+\frac{1}{\sinh\frac{x}{c_1}}\right]$$

$$H_1=\frac{s_1 w_1}{2 E A_1\left(1+\alpha\left[t_2-t_1\right]\right)^2}$$

For any argument $x \div c_1$,

$$c_1=\frac{\text{max. } T_1}{w_1\cosh\frac{x}{c_1}};\quad x=\frac{x}{c_1}\times c_1;\quad s_1=c_1\sinh\frac{x}{c_1}$$

For w_1 see equation (**39**); for A_1 see equation (**43**).

Digitized by Google

The hyperbolic coefficient of G_1 for the argument $x \div c_1$ is the direct reading from the curve of Chart II indexed

$$0.0001 \left[\frac{\cosh \frac{x}{c}}{\frac{x}{c}} + \frac{1}{\sinh \frac{x}{c}} \right], \text{ divided by } 0.0001.$$

After the constants F_1, G_1 and H_1 are computed, the argument $x \div c_2$ which satisfies equation (**63**) is read from Chart II. With the knowledge of $x \div c_2$,

$$c_2 = \frac{x}{\frac{x}{c_2}}; \quad y_2 = c_2 \left(\cosh \frac{x}{c_2} - 1 \right); \quad s_2 = c_2 \sinh \frac{x}{c_2};$$

$$w_2 = \frac{s_1 w_1}{s_2}; \quad \text{max. } T_2 = c_2 w_2 \cosh \frac{x}{c_2}.$$

Second Step. Determination of the catenary at minimum temperature without ice and wind loading, using equation (**60**) changed for convenience to

$$\frac{\sinh \frac{x}{c_3}}{\frac{x}{c_3}} - 1 = F_2 - G_2 + H_2 \left[\frac{\cosh \frac{x}{c_3}}{\frac{x}{c_1}} + \frac{1}{\sinh \frac{x}{c_3}} \right] - 1 \quad (64)$$

where

$$F_2 = \frac{s_1}{x}$$

$$G_2 = \frac{s_1 w_1}{2 E A_1} \left[\frac{\cosh \frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh \frac{x}{c_1}} \right]$$

$$H_2 = \frac{s_1 w''}{2 E A_1}$$

Digitized by Google

For w'' see equation (**40**), other terms are the same as in equation (**63**).

With the knowledge of $x \div c_3$,

$$c_3 = \frac{x}{\frac{x}{c_3}}; \quad y_3 = c_3\left(\cosh\frac{x}{c_3} - 1\right); \quad s_3 = c_3 \sinh\frac{x}{c_3};$$

$$w_3 = \frac{s_1 w''}{s_3}; \quad \text{max. } T_3 = c_3 w_3 \cosh\frac{x}{c_3}.$$

Third Step. Determination of the catenary at maximum temperature, using equation (**62**) changed for convenience to

$$\frac{\sinh\frac{x}{c_4}}{\frac{x}{c_4}} - 1 = F_3 - G_3 + H_3\left[\frac{\cosh\frac{x}{c_4}}{\frac{x}{c_4}} + \frac{1}{\sinh\frac{x}{c_4}}\right] - 1 \quad (\mathbf{65})$$

where

$$F_3 = \frac{s_3}{x}\left(1 + \alpha\left[t_4 - t_1\right]\right)$$

$$G_3 = \frac{s_3 w''}{2 E A_1 \left(1+\alpha\left[t_4 - t_1\right]\right)}\left[\frac{\cosh\frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh\frac{x}{c_3}}\right]$$

$$H_3 = \frac{s_3 w''}{2 E A_1 \left(1+\alpha\left[t_4 - t_1\right]\right)^2}$$

With the knowledge of $x \div c_4$,

$$c_4 = \frac{x}{\frac{x}{c_4}}; \quad y_4 = c_4\left(\cosh\frac{x}{c_4} - 1\right); \quad s_4 = c_4 \sinh\frac{x}{c_4};$$

$$w_4 = \frac{s_1 w''}{s_4}; \quad \text{max. } T_4 = c_4 w_4 \cosh\frac{x}{c_4}.$$

Digitized by Google

The critical catenary is either

$$y_2 = c_2\left(\cosh\frac{x}{c_2} - 1\right) \text{ or } \quad y_4 = c_4\left(\cosh\frac{x}{c_4} - 1\right),$$

whichever equation yields the greatest deflection for a given tower spacing. The determination of the tower spacing and of the corresponding height of tower must be based on the maximum deflection of the critical catenary.

The catenary for any other temperature t_4' somewhere within the range of from t_1 to t_4 can be computed by substituting t_4' for t_4 in equation (**65**). Since this equation is based on the assumption that the cable is free from ice or wind load, the resulting catenaries including those for temperatures below the freezing point, describe the span in calm weather, without sleet deposits on the cable at the low temperatures. Such weather conditions usually prevail at the time of span construction. Hence, a cable strung at any temperature t_4' in calm weather, so that its axis forms a catenary obtained by the use of equation (**65**) for the temperature t_4', would under the most severe weather conditions be subjected to not more nor less than the maximum safe stress. The constructing engineer should have a means of quickly determining the required stringing tension for a given tower spacing and temperature, so that he may guarantee that his span is safe under the most severe weather conditions and that the margin of safety is not too great for economical span construction.

In order to furnish the constructing engineer this necessary information, catenaries for the temperatures t_1, t_4', t_4'' and t_4 are computed with the use of equation (**65**) for a number of arguments $x \div c_4$. The four curves obtained in terms of max T and $2x$ for the range of tower spacing covered by the range of the argument are plotted on a chart and all other curves corresponding to intermediate temperatures are interpolated. A chart of this kind, from which the engineer can directly read the required stringing tension for any length of span and any stringing temperature will hereafter be called a *temperature-tension stringing chart.*

The use of Chart II and of the formulas derived will now be demonstrated in the solution of the following problem:

Problem 3. It is required to draw the temperature-tension stringing chart for a 500,000 cir. mil hard-drawn copper cable.

Digitized by Google

If the cable is suspended from 50-ft. towers so that the minimum clearance of the cable from the ground is 30 ft., what is the maximum permissible tower spacing?

Extreme climatic conditions:

Minimum temperature = − 10 deg. fahr.
Maximum temperature = + 100 deg. fahr.
Maximum ice loading = ½-inch (12.7 mm.) layer enveloping cable.
Maximum wind pressure = 10 lb. per square ft. area normal to direction of wind.

Specification of Cable:

Number of strands in cable = 37.
Modulus of elasticity = 16,000,000.
Ultimate tensile strength of one strand = 673 lb. (305.2 kg.).
Temperature coefficient of linear expansion 0.00000922 (fahr. scale).

Diameter of strand = 0.1162 in. (2.9 mm.)
Diameter of cable = 0.8134 in. (20.6 mm.)
Weight per ft. of cable = 1.54 lb. (0.6 kg.)

} Measurements taken at 75 deg. fahr. with cable free from mechanical stress.

The ultimate tensile strength of the cable to be not more than 0.9 the combined ultimate tensile strength of its strands.

$$673 \times 37 \times 0.9 = 22{,}411 \text{ lb. } (10{,}165.3 \text{ kg.})$$

The elastic limit to be taken at 50 per cent of the ultimate breaking stress.

$$22{,}411 \times 0.5 = 11{,}206 \text{ lb. } (5082.9 \text{ kg.})$$

The maximum tension on the cable should not exceed 75 per cent of the tension at the elastic limit.

$$11{,}206 \times 0.75 = 8400 \text{ lb. } (3810.1 \text{ kg.})$$

Since all preceding formulas describe the characteristics of a suspended cylindrical solid, it will be of advantage to substitute for the stranded cable a cylindrical solid which has the same characteristics as the actual stranded cable in regard to temperature changes, changes in tension, weight per unit length and ice and wind load. The ice and wind load on the equivalent cylindrical solid will be the same as the ice and wind load on the

Digitized by Google

stranded cable, if the cylindrical solid has the same diameter as the outside diameter of the stranded cable. The inside area of a cylindrical envelope surrounding the stranded cable is, as well as the actual cross-sectional area of metal of the cable, directly proportional to the square of the diameter of the strand; hence, as far as the influence of temperature is concerned, both areas are affected in the same proportion. Similarly, the changes in both areas due to changes in tension are proportional to the changes in area of the strand; however, since the modulus of elasticity is measured on the basis of the cross-sectional area of metal, it must be changed in inverse proportion to the area for the same strain, so that

$$E' \times A' = E \times A$$

where,

E' = modulus of elasticity for stranded cable.
E = modulus of elasticity for equivalent cylindrical solid.
A' = cross-sectional area of metal of stranded cable.
A = cross-sectional area of equivalent cylindrical solid.

Hence,

$$E = \frac{E' A'}{A} = \frac{16{,}000{,}000 \times 37 \times 0.1162^2}{0.8134^2} = 12{,}082{,}000$$

Revised specification of cable, using the foot as the unit of length and the pound as the unit of force:

A = Cross-sectional area free from stress

$$= \frac{\pi \times 0.8314^2}{4 \times 144} = 0.00361$$

w = Weight per foot length free from stress = 1.54
E = Modulus of elasticity = 12,082,000 × 144 = 1,739,808,000
α = Coefficient of linear expansion = 0.00000922
max T = Maximum safe stress on cable = 8400
t = Temperature at which measurements of A and w were taken = 75

Other given data:

t_1 = Minimum temperature = − 10
t_2 = Temperature at freezing point = + 32
t_4 = Maximum temperature = + 100
a = Maximum thickness of ice layer enveloping cable = 0.04167

Digitized by Google

u = Weight per cubic foot of ice = 57.37

v = Maximum wind pressure per square foot area normal to direction of wind = 10

For the temperature-tension stringing chart two other temperatures $t_4' = +30$ and $t_4'' = +60$ will be used in connection with equation (**65**).

From equation (**40**)

$$w'' = \frac{1.54 \times 1{,}739{,}808{,}000 \times 0.00361\,(1 - 0.00000922\,[75 + 10])}{1{,}739{,}808{,}000 \times 0.00361\,(1 - 0.00000922\,[75+10])^2 + 8400} = 1.5391$$

From equation (**41**)

$$i = 57.37 \times 3.1416 \times 0.04167 \left[0.04167 + 2 \times 0.00361\,(1 - 0.00000922\,[75 + 10])^2 \left(\frac{1{,}739{,}808{,}000}{3.1416\,(1739808000 \times 0.00361(1-0.00000922[75+10])^2+8400]}\right)^{\frac{1}{2}}\right] = 0.8212$$

From equation (**42**)

$$p = 2 \times 10\left[0.04167 + 0.00361(1 - 0.00000922[75 + 10])^2 \left(\frac{1{,}739{,}808{,}000}{3.1416[1739808000 \times 0.00361(1-0.00000922[75+10])^2+8400]}\right)^{\frac{1}{2}}\right] = 1.5100$$

From equation (**39**)

$$w_1 = [(1.5391 + 0.8212)^2 + 1.51^2]^{\frac{1}{2}} = 2.802$$

From equation (**43**)

$$A_1 = \frac{1{,}739{,}808{,}000 \times 0.00361^2\,(1 - 0.00000922\,[75 + 10])^4}{1{,}739{,}808{,}000 \times 0.00361\,(1 - 0.00000922\,[75+10])^2 + 8400} = 0.003598$$

In the following five tables the computations necessary for the solution of the problem are carried out systematically. Tables I, II and III determine the critical catenary and Tables II, III, IV and V give the data necessary for the temperature-tension stringing chart. The columns of figures are indexed successively from 1 to 44. In the space below the index of a column is given the relation of the values in that column to the values computed in preceding columns. For instance, in column

Digitized by Google

of Table III indexed 31 are given values obtained by multiplying the values given in column of Table II indexed 24 by the constant $12{,}281 \times 10^{-11}$. The second space below the indices indicates the significance of the values in the column with respect to the working equation at the top of the table.

A comparison of the deflections y_2 and y_4 given in column 15 of Table I and column 39 of Table III shows that the critical catenary is the catenary formed by the cable at the maximum temperature + 100 deg. fahr. The difference between the deflection of the cable at the freezing point under maximum ice loading and the deflection at the maximum temperature is,

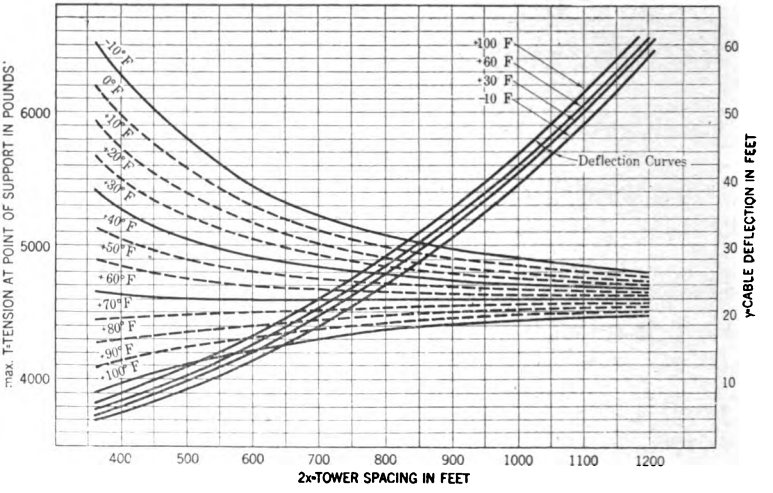


FIG. 3—TEMPERATURE-TENSION STRINGING CHART 500,000 CIR. MILS HARD-DRAWN COPPER CABLE

Maximum tension to be not more nor less than 8[illegible] lb. at 10 deg. fahr. under wind load of 10 lb. per sq. ft. and ice load of one-half inch layer enveloping cable.

however, very small which shows the necessity of performing the deflection computations for both weather conditions in every case.

With a given height of tower and a given maximum cable deflection the critical catenary determines the tower spacing. The height of towers given in this problem is 50 ft., and since the deflection of the cable is not to exceed 20 ft. (50 − 30), the tower spacing is found directly from the curves of Fig. 3. The abscissa corresponding to the ordinate $y = 20$ of the deflection curve + 100 deg. fahr. (critical catenary) is 665. Hence the maximum permissible tower spacing is 665 ft. (202.6 m.)

Digitized by Google

TABLE I. CATENARY AT FREEZING POINT.

Working Formula. [See equation (63)]

$$\frac{\sinh\frac{x}{c_2}}{\frac{x}{c_2}} - 1 = F_1 - G_1 + H_1 \times \left[\frac{\cosh\frac{x}{c_2}}{\frac{x}{c_2}} + \frac{1}{\sinh\frac{x}{c_2}}\right] - 1$$

$$F_1 = \frac{s_1}{x} \times (1 + 0.0000000322[32 + 1)]) = \frac{s_1}{x} \times 1.0003372$$

$$G_1 = s_1 \times \frac{2.802}{2 \times 1{,}739{,}808{,}000 \times 0.003598 \times 1.0003872} \left[\frac{\cosh\frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh\frac{x}{c_1}}\right]$$

$$= s_1 \times 0.00000022373 \left[\frac{\cosh\frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh\frac{x}{c_1}}\right]$$

$$H_1 = s_1 \times \frac{2.802}{2 \times 1{,}739{,}808{,}000 \times 0.003598 \times 1.0003872^2} = s_1 \times 0.00000022364$$

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\frac{2997.86}{\cosh(1)}$	(1) × (2)	(2) × sinh (1)	$\frac{(4)}{(3)}$	(5) × 1.000387	(4) × 22,373 ×10⁻¹¹	(1) & Ch't II
$\frac{x}{c_1}$ = Assumed Argument	$c_1 = \frac{8400}{2.802\cosh\frac{x}{c_1}}$	$x = \frac{x}{c_1} \times c_1$	$s_1 = c_1 \sinh\frac{x}{c_1}$	$\frac{s_1}{x}$	F_1	$\frac{G_1}{\cosh\frac{x}{c_1} + \frac{1}{\sinh\frac{x}{c_1}}}$	$\cosh\frac{x}{c_1} + \frac{1}{\sinh\frac{x}{c_1}}$
0.06	2992.47	179.548	179.656	1.000599	1.000986	0.00004019	33.36
0.08	2988.29	239.063	239.318	1.001068	1.001456	0.00005354	25.03
0.10	2982.94	298.294	298.791	1.001667	1.002055	0.00006685	20.03
0.12	2976.40	357.168	358.026	1.002402	1.002790	0.00008010	16.71
0.14	2968.72	415.621	416.980	1.003270	1.003658	0.00009329	14.33
0.16	2959.89	473.582	475.605	1.004272	1.004661	0.00010641	12.55
0.18	2949.94	530.989	533.861	1.005409	1.005798	0.00011944	11.17
0.20	2938.89	587.778	591.704	1.006680	1.007069	0.00013238	10.07

(9)	(10)	(11)	(12)	(13)	(14)	(15)
(7) × (8)	(6) − (9) − 1	$\frac{(7)}{1.0003872}$	(10), (11) & Ch't II	$\frac{(3)}{(12)}$	− 1 + cosh (12)	(13) × (14)
G_1	$F_1 - G_1 - 1$	H_1	$\frac{x}{c_2}$	$c_2 = \frac{x}{\frac{x}{c_2}}$	$\frac{y^2}{c_2} = \cosh\frac{x}{c_2} - 1$	y_2
0.001341	− 0.000355	0.0000402	0.0696	2579.71	0.00242	6.24
0.001340	+ 0.000116	0.0000535	0.0889	2689.12	0.00395	10.62
0.001339	+ 0.000716	0.0000668	0.1082	2756.88	0.00586	16.17
0.001338	+ 0.001452	0.0000801	0.1275	2801.32	0.00814	22.80
0.001337	+ 0.002321	0.0000933	0.1468	2831.21	0.01080	30.57
0.001335	+ 0.003326	0.0001064	0.1662	2849.46	0.01384	39.43
0.001334	+ 0.004464	0.0001194	0.1857	2859.40	0.01729	49.43
0.001333	+ 0.005736	0.0001323	0.2053	2863.02	0.02115	60.55

Digitized by Google

TABLE II CATENARY AT TEMPERATURE – 10 DEG. FAHR.

Working Formula. [See equation (64)]

$$\frac{\sinh \frac{x}{c_3}}{\frac{x}{c_3}} - 1 = F_2 - G_2 + H_2 \left[\frac{\cosh \frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh \frac{x}{c_3}} \right] - 1$$

$$F_2 = \frac{s_1}{x} = \text{given in col. (5), Table I.}$$

$$G_2 = s_1 \frac{2.802}{2 \times 1{,}739{,}808\,000 \times 0.003598} \left[\frac{\cosh \frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh \frac{x}{c_1}} \right]$$

$$= s_1 \times 0.00000022381 \times \text{value given in col. 8, Table I.}$$

$$H_2 = s_1 \times \frac{1.5391}{2 \times 1{,}739{,}808{,}000 \times 0.003598} = s_1 \times 0.00000012294$$

(16)	(17)	(18)	(19)	(20)	(21)
(4) × 22,381 × 10^{-11}	(8) × (16)	(5) − (17) − 1	(4) × 12,294 × 10^{-11}	(18), (19) & Ch't II	(3) / (20)
$\frac{G_2}{\frac{\cosh \frac{x}{c_1}}{\frac{x}{c_1}} + \frac{1}{\sinh \frac{x}{c_1}}}$	G_2	$F_2 - G_2 - 1$	H_2	$\frac{x}{c_3}$	$c_3 = \frac{x}{\frac{x}{c_3}}$
0.00004021	0.001341	−0.000742	0.0000221	0.0424	4234.62
0.00005356	0.001340	−0.000272	0.0000294	0.0628	3806.74
0.00006687	0.001339	+0.000328	0.0000367	0.0846	3525.93
0.00008013	0.001338	+0.001064	0.0000440	0.1066	3350.54
0.00009332	0.001337	+0.001938	0.0000513	0.1282	3241.98
0.00010644	0.001336	+0.002936	0.0000585	0.1494	3169.89
0.00011948	0.001335	+0.004074	0.0000656	0.1704	3116.13
0.00013242	0.001334	+0.005346	0.0000728	0.1913	3072.54

(22)	(23)	(24)	(25)	(26)	(27)	(28)
cosh (20) −1	(21) × (22)	(21) × sinh (20)	(4) / (24)	(25) × 1.5391	(21) × cosh (20)	(26) × (27)
$\frac{y_3}{c_3} = \cosh \frac{x}{c_3} - 1$	y_3	$s_3 = c_3 \sinh \frac{x}{c_3}$	$\frac{s_1}{s_3}$	$w_3 = \frac{s_1}{s_3} w''$	$\frac{\max T_3}{w_3} = c_3 \cosh \frac{x}{c_3}$	$\max T_3$
0.00090	3.81	179.590	1.00037	1.5397	4238.43	6525.91
0.00197	7.50	239.216	1.00043	1.5398	3813.97	5872.75
0.00358	12.62	298.646	1.00049	1.5399	3538.55	5448.01
0.00568	19.03	357.838	1.00055	1.5399	3369.57	5188.80
0.00823	26.68	416.757	1.00061	1.5400	3268.66	5033.74
0.01118	35.44	475.325	1.00059	1.5400	3205.33	4936.21
0.01455	45.24	533.575	1.00057	1.5400	3161.47	4868.66
0.01836	56.42	591.372	1.00056	1.5399	3128.95	4818.27

Digitized by Google

TABLE III. CATENARY TEMPERATURE + 100 DEG. FAHR.

Working Formula. [See equation (65)]

$$\frac{\sinh\frac{x}{c_4}}{\frac{x}{c_4}} - 1 = F_3 - G_3 + H_3\left[\frac{\cosh\frac{x}{c_4}}{\frac{x}{c_4}} + \frac{1}{\sinh\frac{x}{c_4}}\right] - 1$$

$$F_3 = s_3/x \times (1 + 0.00000922\,[100 + 10]) = s_3 \times 1.001014$$

$$G_3 = s_3 \times \frac{1.5391}{2\times1{,}739{,}808{,}000\times0.003598\times1.001014}\left[\frac{\cosh\frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh\frac{x}{c_3}}\right]$$

$$= s_3 \times 0.00000012281\left[\frac{\cosh\frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh\frac{x}{c}}\right]$$

$$H_3 = s_3 \times \frac{1.5391}{2\times1{,}739{,}808{,}000\times0.003598\times1.001014^2} = s_3 \times 0.00000012268$$

(29)	(30)	(31)	(32)	(33)	(34)	(35)
(24) / (3)	(29) × 1.001014	(24) × 12,281 × 10^{-11}	(20) & Ch't II	(31) × (32)	(30) − (33) − 1	(24) × 12,268 × 10^{-11}
$\frac{s_3}{x}$	F_3	$\frac{G_3}{\cosh\frac{x}{c_3}+\frac{1}{\sinh\frac{x}{c_3}}}$	$\frac{1}{\cosh\frac{x}{c_3}+\frac{1}{\sinh\frac{x}{c_3}}}$	G_3	$F_3 - G_3 - 1$	H_3
1.000234	1.001248	0.00002206	47.16	0.001040	+0.000208	0.0000220
1.000640	1.001655	0.00002938	31.83	0.000935	+0.000720	0.0000294
1.001180	1.002195	0.00003668	23.67	0.000868	+0.001327	0.0000366
1.001876	1.002892	0.00004395	18.80	0.000826	+0.002066	0.0000439
1.002735	1.003750	0.00005118	15.65	0.000801	+0.002949	0.0000511
1.003680	1.004698	0.00005838	13.43	0.000784	+0.003914	0.0000583
1.004870	1.005889	0.00006553	11.80	0.000773	+0.005116	0.0000655
1.006114	1.007134	0.00007263	10.52	0.000764	+0.006370	0.0000726

(36)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)
(34), (35) & Ch't II	(3) / (36)	cosh (36) − 1	(37) × (38)	(37) × sinh (36)	(4) / (40)	(41) × 1.5391	(37) + (39)	(42) × (43)
$\frac{x}{c_4}$	$c_4 = \frac{x}{\frac{x}{c_4}}$	$\frac{y_4}{c_4} = \cosh\frac{x}{c_4} - 1$	y_4	$s_4 = c_4\sinh\frac{x}{c_4}$	$\frac{s_1}{s_4}$	$w = \frac{s_1}{s_4}w'$	$\frac{\max T_4}{w_4} = c_4\cosh\frac{x}{c_4}$	$\max T_4$
0.0710	2528.85	0.00252	6.37	179.690	0.99981	1.5388	2535.22	3901
0.0905	2741.58	0.00410	10.83	239.380	0.99974	1.5387	2652.41	4081
0.1095	2724.15	0.00600	16.34	298.894	0.99969	1.5386	2740.49	4216
0.1285	2779.52	0.00823	22.96	358.141	0.99966	1.5386	2802.48	4312
0.1475	2817.77	0.01089	30.69	417.143	0.99964	1.5385	2848.46	4382
0.1665	2844.34	0.01389	39.50	475.773	0.99963	1.5385	2883.84	4437
0.1865	2847.13	0.01744	49.65	534.065	0.99961	1.5385	2896.78	4457
0.2060	2853.30	0.02129	60.74	591.946	0.99960	1.5385	2914.04	4483

Digitized by Google

TABLE IV. CATENARY AT TEMPERATURE + 30 DEG. FAHR.

Working Formula. [See equation (65)]

$$\frac{\sinh \frac{x}{c_4'}}{\frac{x}{c_4'}} - 1 = F_3' - G_3' + H_3' \left[\frac{\cosh \frac{x}{c_4'}}{\frac{x}{c_4'}} + \frac{1}{\sinh \frac{x}{c_4'}} \right] - 1$$

$$F_3' = s_3 \times (1 + 0.00000922\,[30 + 10]) = s_3 \times 1.0003688$$

$$G_3' = s_3 \times \frac{1.5391}{2 \times 1{,}739{,}808{,}000 \times 0.003598 \times 1.0003688} \left[\frac{\cosh \frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh \frac{x}{c_3}} \right]$$

$$= s_3 \times 0.00000012289 \times \text{value given in col. 32, Table III}$$

$$H_3' = s_3 \times \frac{1.5391}{2 \times 1{,}739{,}808{,}000 \times 0.003598 \times 1.0003688^2} = s_3 \times 1.00000012285$$

(30)′	(31)′	(33)′	(34)′	(35)′	(36)′
(29) × 1.0003688	(24) × 12,289 × 10^{-11}	(31)′ × (32)	(30)′ − (33)′ − 1	(24) × 12,285 × 10^{-11}	(34)′ & (35)′ & Ch't II
F_3'	$G_3' \Big/ \left(\cosh \frac{x}{c_3'} + \frac{1}{\sinh \frac{x}{c_3'}} \right)$	G_3'	$F_3' - G_3' - 1$	H_3'	$\frac{x}{c_4'}$
1.000603	0.00002207	0.001041	−0.000438	0.0000221	0.0510
1.001009	0.00002939	0.000936	+0.000073	0.0000294	0.0727
1.001549	0.00003670	0.000869	+0.000680	0.0000367	0.0936
1.002245	0.00004397	0.000827	+0.001418	0.0000440	0.1145
1.003105	0.00005121	0.000802	+0.002303	0.0000512	0.1354
1.004090	0.00005841	0.000785	+0.003265	0.0000584	0.1561
1.005241	0.00006557	0.000774	+0.004467	0.0000655	0.1766
1.006485	0.00007267	0.000765	+0.005720	0.0000727	0.1968

(37)′	(38)′	(39)′	(40)′	(41)′	(42)′	(43)′	(44)′
(3) / (36)′	cosh (36)′ − 1	(37)′ × (38)′	(37)′ × sinh (36)′	(4) / (40)′	(41)′ × 1.5391	(37)′ + (39)′	(42)′ × (43)′
c_4'	$\frac{y_4'}{c_4'} = \cosh \frac{x}{c_4'} - 1$	y_4'	$s_4' = c_4' \sinh \frac{x}{c_4'}$	$\frac{s_1}{s_4'}$	$w_4' = \frac{s_1}{s_4'} w''$	$\frac{\max T_4'}{w_4'} = c_4 \cosh \frac{x}{c_4'}$	$\max T_4'$
3520.55	0.00130	4.58	179.618	1.00021	1.5394	3525.1	5427
3288.35	0.00264	8.68	239.268	1.00021	1.5394	3297.0	5074
3186.90	0.00438	13.95	298.730	1.00021	1.5394	3200.9	4927
3119.37	0.00657	20.49	357.948	1.00022	1.5394	3139.9	4833
3069.58	0.00918	28.18	416.880	1.00024	1.5395	3097.8	4768
3033.84	0.01221	37.05	475.494	1.00023	1.5395	3070.9	4727
3006.73	0.01564	47.03	533.755	1.00020	1.5394	3053.8	4701
2986.67	0.01943	58.04	591.600	1.00018	1.5393	3044.7	4687

Digitized by Google

TABLE V. CATENARY AT TEMPERATURE + 60 DEG. FAHR.

Working Formula. [See equation (65)]

$$\frac{\sinh\frac{x}{c_4''}}{\frac{x}{c_4''}} - 1 = F_3'' - G_3'' + H_3'' \left[\frac{\cosh\frac{x}{c_4''}}{\frac{x}{c_4''}} + \frac{1}{\sinh\frac{x}{c_4''}}\right] - 1$$

$$F_3'' = s_3 \times (1 + 0.00000922[60 + 10]) = s_3 \times 1.0006454$$

$$G_3'' = s_3 \times \frac{1.5391}{2 \times 1{,}739{,}808{,}000 \times 0.003598 \times 1.0006454} \left[\frac{\cosh\frac{x}{c_3}}{\frac{x}{c_3}} + \frac{1}{\sinh\frac{x}{c_3}}\right]$$

$= s_3 \times 0.00000012286 \times$ value given in col. 32, Table III

$$H_3'' = s \times \frac{1.5391}{2 \times 1{,}739{,}808{,}000 \times 0.003598 \times 1.0006454^2} = s_3 \times 1.00000012281$$

(30) ''	(31) ''	(33) ''	(34) ''	(35) ''	(36) ''
(29) × 1.0006454	(24) × 12,286 × 10^{-11}	(31) '' × (32)	(30) '' − (33) '' − 1	(24) × 12,281 × 10^{-11}	(34) '', (35) '' & Ch't II
F_3''	$\frac{G_3''}{\cosh\frac{x}{c_3} + \frac{1}{\frac{x}{c_3}\sinh\frac{x}{c_3}}}$	G_3''	$F_3'' - G_3'' - 1$	H_3''	$\frac{x}{c_4''}$
1.000880	0.00002206	0.001040	−0.000160	0.0000221	0.0595
1.001286	0.00002938	0.000935	+0.000351	0.0000294	0.0800
1.001826	0.00003669	0.000869	+0.000957	0.0000367	0.1005
1.002523	0.00004397	0.000827	+0.001696	0.0000440	0.1205
1.003382	0.00005120	0.000802	+0.002580	0.0000512	0.1405
1.004328	0.00005840	0.000785	+0.003543	0.0000584	0.1605
1.005519	0.00006559	0.000774	+0.004745	0.0000655	0.1805
1.006718	0.00007266	0.000765	+0.005953	0.0000726	0.2000

(37) ''	(38) ''	(39) ''	(40) ''	(41) ''	(42) ''	(43) ''	(44)"
$\frac{(3)}{(36)''}$	cosh (36) '' −1	(37) '' × (38) ''	(37) '' × sinh (36)"	$\frac{(4)}{(42)''}$	(41) '' × 1.5391	(37) '' + (39)"	(42)" × (43)"
c_4''	$\frac{y_4''}{c_4''} = \cosh\frac{x}{c_4''} - 1$	y_4''	$s_4'' = c_4'' \sinh\frac{x}{c_4''}$	$\frac{s_1}{s_4''}$	$w_4'' = \frac{s_1}{s_4''} w''$	$\frac{\max T_4''}{w_4''} = c_4'' \cosh\frac{x}{c_4''}$	$\max T_4''$
3017.61	0.00177	5.34	179.658	0.99993	1.5390	3023.0	4652
2988.30	0.00320	9.56	239.333	0.99994	1.5390	2997.9	4614
2968.10	0.00505	14.99	298.799	0.99997	1.5390	2983.1	4591
2964.05	0.00727	21.55	358.028	0.99998	1.5391	2985.6	4595
2958.16	0.00989	29.25	417.012	0.99998	1.5391	2987.4	4598
2950.67	0.01291	38.09	475.618	0.99998	1.5391	2988.8	4600
2941.77	0.01633	48.04	533.872	0.99999	1.5391	2989.8	4602
2938.89	0.02007	56.98	591.716	0.99999	1.5391	2997.9	4614

Digitized by Google

The temperature-tension stringing chart (Fig. 3) is plotted from the values given in columns 28 Table II, 44 Table III, 44′ Table IV and 44″ Table V. The dotted curves for intermediate temperatures have been interpolated. The deflection curves for the temperatures − 10 deg., + 30 deg., + 60 deg. and + 100 deg. have also been drawn on the same chart so as to give an effective check on the work of stringing.

Supposing the cable is to be suspended at a temperature of + 50 deg. fahr. from towers spaced 500 ft. (152.4 m.) apart, then, according to the chart, the tension at the point of support must be 4750 lb. (2154.5 kg.) with a corresponding deflection of 10.2 ft. (3.1 m.) If the same cable at the same temperature were to be strung between towers spaced 1000 ft. (304.8 m.) apart, the tension would have to be 4650 lb. (2109.2 kg.) with a corresponding cable deflection of 42.5 ft. (12.9 m.).

The computations for the Tables I to V consisting of 44 mathematical operations for each argument are all derived from the values given in the first columns of Table I, and a slight error made in those columns might be accumulative during each succeeding step leading to appreciable errors in the last computations. It is of importance, therefore, to begin the work with great precision using hyperbolic functions of the arguments in column 1 computed accurately to the eighth decimal. Below is given a table of natural hyperbolic functions of arguments which cover the range of ordinary span designs.

$\frac{x}{c}$	$\sinh\frac{x}{c}$	$\cosh\frac{x}{c}$
0.04	0.0400106675	1.0008001061
0.06	0.0600360065	1.0018005401
0.08	0.0800853606	1.0032017064
0.10	0.1001666750	1.0050041075
0.12	0.1202882070	1.0072086441
0.14	0.1404577820	1.0098160171
0.16	0.1606835410	1.0128270898
0.18	0.1809735759	1.0162437873
0.20	0.2013360025	1.0200667556
0.22	0.2217787996	1.0242977643
0.24	0.2423106127	1.0289385057

Digitized by Google

(C) The Most Economical Tower Spacing

The most important item in the cost of a transmission line is the cost of the supports for the line conductors. The following investigation will disclose the physical laws which govern the magnitude of this cost item and will evolve a method of its accurate computation in connection with the determination of some important mechanical features of the line.

The total cost of the line supports is directly proportional to the cost of each support and to the number of supports used for the entire line. For a minimum total cost, the cost of each support must be a minimum and the number of supports for the line must be a minimum, that is, the tower spacing must be a maximum. As demonstrated in the preceding section the critical catenary formed by the cable will determine the required height of support with a given tower spacing or it will determine the tower spacing with a given height of support, provided, the minimum clearance between cable and ground is fixed. The catenary equation also shows that the greater the tower spacing, the greater will be the height of the support. Since the cost of the support increases with the height of the support, an increase in tower spacing increases the cost of each support and at the same time decreases the total number of supports required for the given line. Hence, the total cost of the supports will be a minimum when the tower spacing is such, that if increased by an increment, the rate of increase in cost of the support multiplied by the number of supports is equal to the rate of decrease of the total cost of the supports due to a decrease of their number

The above analysis shows that for the determination of the minimum total cost of the line supports it is necessary to segregate the cost items which are a function of the tower spacing only, from the cost items which are a function of the tower spacing and of the height of the support. The total cost must be expressed in terms of these two groups of items so that a mathematical solution for a minimum cost may be performed.

The cost of a line support comprises the following items;

1. Cost of tower at place of erection.
2. Cost of erection of tower.
3. Cost of lease or purchase of tower site.
4. Cost of foundation installed.

Digitized by Google

5. Cost of location and inspection of line support.
6. Cost of insulators at location of tower.
7. Cost of placing insulators and cable.

Item 1. The weight of the tower is proportional to the maximum cable stress for which it is designed. For the same stress, an increase in the height of the tower increases its weight in proportion to the square of its height. Since the cost of the tower is proportional to its weight, the magnitude of item 1 is directly proportional to the square of the height of the tower.

Item 2. The given stress for which the tower is designed practically fixes the weight per unit length and the lengths of its structural members. Hence, an increase in the height of the tower increases the number of its structural members, and in consequence the cost of erection, in direct proportion to the square of the height of the tower.

Item 3. Since in practical tower design the ratio of the height of the tower to the width of its base is a constant, the area of the tower site and in consequence the cost of its lease or purchase will also vary in direct proportion to the square of the height of the tower.

Item 4. The cost of the foundation is directly proportional to the tension for which the tower is designed and is practically independent of the height of the tower.

Items 5, 6 and 7 are independent of the mechanical features of the towers and are constants for given transportation rates and market conditions of materials and labor. The magnitude of item 6 is practically proportional to the transmission voltage and is fixed for a given transmission voltage.

The above analysis of the different cost items is based on the cost of a standard three-phase transmission line.

Let L = length of the transmission line.

$2x$ = tower spacing.

h = height of tower.

k_1 = minimum clearance of cable to ground.

y = maximum deflection of the catenary formed by the cable.

Digitized by Google

The number of line supports is, then

$$N = \frac{L}{2x} \tag{66}$$

and the height of the support is

$$h = k_1 + y \tag{67}$$

The total cost of the line supports is

$$M = N\,(h^2\,k_2 + k_3) \tag{68}$$

where:

$h^2\,k_2$ = sum of items 1, 2 and 3.

k_3 = sum of items 4, 5, 6 and 7.

Substituting equations (**66**) and (**67**) into (**68**):

$$M = \frac{L}{2x}(k_2\,[k_1 + y]^2 + k_3)$$

Substituting for y in above equation its equivalent from equation (**11**),

$$M = \frac{L}{2x}\left(k_2\left[k_1 + c\left(\cosh\frac{x}{c} - 1\right)\right]^2 + k_3\right) \tag{69}$$

For a minimum or maximum cost the derivative of equation (**69**) with respect to x must be equal to zero:

$$\frac{d\,M}{dx} = 0 = \frac{L}{2}\left(\frac{2\,k_2\,c\cosh\frac{x}{c}\sinh\frac{x}{c}}{x} - \frac{k_2\,c^2\cosh\frac{x}{c}}{x^2}\right.$$

$$\left. - \frac{2\,k_2\,c\sinh\frac{x}{c}}{x} + \frac{2\,k_2\,c^2\cosh\frac{x}{c}}{x^2}\right.$$

Digitized by Google

$$- \frac{k_2 c^2}{x^2} + \frac{2 k_2 k_1 \sinh \frac{x}{c}}{x} - \frac{2 k_2 k_1 c \cosh \frac{x}{c}}{x^2} + \frac{2 k_2 k_1 c}{x^2}$$

$$- \frac{k_2 k_1^2}{x^2} - \frac{k_3}{x^2}\Big)$$

$$= 2 cx \cosh \frac{x}{c} \sinh \frac{x}{c} - c^2 \cosh^2 \frac{x}{c} - 2 cx \sinh \frac{x}{c}$$

$$+ 2 c^2 \cosh \frac{x}{c} - c^2$$

$$+ 2 k_1 x \sinh \frac{x}{c} - 2 k_1 c \cosh \frac{x}{c} + 2 k_1 c - k_1^2 - \frac{k_3}{k_2}$$

But $x = c \times \frac{x}{c}$, hence,

$$0 = c^2 \Big(2 \frac{x}{c} \cosh \frac{x}{c} \sinh \frac{x}{c} - \cosh^2 \frac{x}{c} - 2 \frac{x}{c} \sinh \frac{x}{c}$$

$$+ 2 \cosh \frac{x}{c} - 1\Big)$$

$$+ 2 ck_1 \Big(\frac{x}{c} \sinh \frac{x}{c} - \cosh \frac{x}{c} + 1\Big) - k_1^2 - \frac{k_3}{k_2}$$

Simplifying:

$$c^2 \Big(\cosh \frac{x}{c} - 1\Big)\Big(2 \frac{x}{c} \sinh \frac{x}{c} - \cosh \frac{x}{c} + 1\Big)$$

$$+ 2 ck_1 \Big(\frac{x}{c} \sinh \frac{x}{c} - \cosh \frac{x}{c} + 1\Big) = k_1^2 + \frac{k_3}{k_2}$$

Digitized by Google

from which

$$c = -\frac{k_1\left(\frac{x}{c}\sinh\frac{x}{c} - \cosh\frac{x}{c} + 1\right)}{\left(\cosh\frac{x}{c} - 1\right)\left(2\frac{x}{c}\sinh\frac{x}{c} - \cosh\frac{x}{c} + 1\right)}$$

$$\pm\left[\frac{\left(k_1^2 + \frac{k_3}{k_2}\right)\left(\cosh\frac{x}{c} - 1\right)\left(2\frac{x}{c}\sinh\frac{x}{c} - \cosh\frac{x}{c} + 1\right) + k_1^2\left(\frac{x}{c}\sinh\frac{x}{c} - \cosh\frac{x}{c} + 1\right)^2}{\left(\cosh\frac{x}{c} - 1\right)^2\left(2\frac{x}{c}\sinh\frac{x}{c} - \cosh\frac{x}{c} + 1\right)^2}\right]^{\frac{1}{2}}$$

Simplifying:

$$c = -\frac{k_1\left[\frac{x}{c}\sinh\frac{x}{c} - \left(\cosh\frac{x}{c} - 1\right)\right]}{\left(\cosh\frac{x}{c} - 1\right)\left[2\frac{x}{c}\sinh\frac{x}{c} - \left(\cosh\frac{x}{c} - 1\right)\right]}$$

$$\pm\frac{\left[\frac{k_3}{k_2}\left(\cosh\frac{x}{c} - 1\right)\left[2\frac{x}{c}\sinh\frac{x}{c} - \left(\cosh\frac{x}{c} - 1\right)\right] + \left(k_1\frac{x}{c}\sinh\frac{x}{c}\right)^2\right]^{\frac{1}{2}}}{\left(\cosh\frac{x}{c} - 1\right)\left[2\frac{x}{c}\sinh\frac{x}{c} - \left(\cosh\frac{x}{c} - 1\right)\right]} \qquad (70)$$

Digitized by Google

Equation (**70**) yields the minimum cost if the positive sign before the radical is used.

For a given clearance of the cable to ground k_1 and a given hyperbolic argument, equation (**70**) contains only one variable, the ratio $k_3 \div k_2$. In practical line design the possible range of this ratio falls within the limits 500 and 1500. In the following table are given the solutions of equation (**70**) for $k_3 \div k_2 = 500$, $k_3 \div k_2 = 1000$ and $k_3 \div k_2 = 1500$ with arguments ranging between 0.06 and 0.20. The results are plotted in the form of curves of Fig. 4. The dotted curves were drawn by interpolation.

$k_1 = 30$						
	$k_3 \div k_2 = 500$		$k_3 \div k_2 = 1000$		$k_3 \div k_2 = 1500$	
$\frac{x}{c}$	c	$2x$	c	$2x$	c	$2x$
0.06	7661	919	9480	1138	11104	1332
0.08	4310	690	5330	853	6243	999
0.10	2755	551	3409	682	3979	796
0.12	1913	459	2366	568	2771	665
0.14	1403	393	1736	486	2034	570
0.16	1073	343	1329	425	1555	478
0.18	847	305	1048	377	1227	442
0.20	686	274	848	339	982	393

The most economical tower spacing is the abscissa of the intersection point between the curve $k_3 \div k_2$ corresponding to the given transportation rates and market prices of material and labor, and the curve of critical catenaries for the given cable plotted in terms of $2x$ and c; provided that the minimum clearance of the cable to ground is 30 ft. (9.1 m.). For any other clearance a different set of curves has to be computed with the use of equation (**70**).

The significance of the $k_3 \div k_2$ curves obtained by equation (**70**) will now be demonstrated by the solution of the following problem:

Problem 4. What is the most economical tower spacing for the cable specified in problem 3 of section B?

The cost data of a transmission line built under practically

Digitized by Google

the same as the present conditions concerning transportation charges and prices of labor and materials are as follows:

1.	Cost of tower at place of erection	$190.00
2.	Cost of erection of tower	30.00
3.	Cost of tower site	10.00
4.	Cost of foundation installed	125.00
5.	Cost of location and inspection of support	13.00
6.	Cost of insulators at location of tower	30.00
7.	Cost of placing insulators and cable	10.00

The height of the point of cable support above the tower footing is 37 ft. (11.2 m.). The tower is designed for a tension

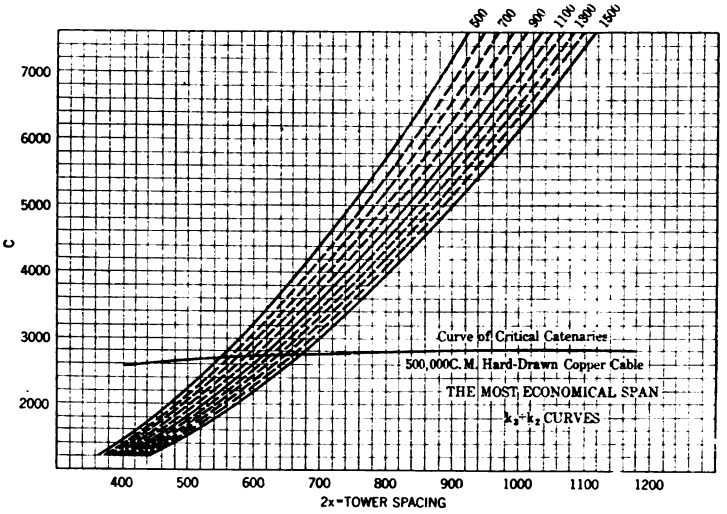


FIG. 4

of 6000 lb. (2721.5 kg.) per cable. The transmission voltage is 150,000.

The transmission voltage of the line formed by the cable specified in problem 3 is to be 110,000.

Solution. If the tower specified above were designed for a tension of 8400 lb. (3810.1 kg.). per cable, its cost would be

$$\$ \frac{190 \times 8400}{6000} = \$266.00$$

and the cost of the foundation,

$$\$ \frac{125 \times 8400}{6000} = \$175.00$$

Digitized by Google

For a transmission voltage of 110,000 the cost of the insulators will be approximately

$$\$ \frac{30 \times 110{,}000}{150{,}000} = \$22.00$$

The remaining cost items are not affected by the tension and transmission voltage.

Cost data revised for different tension and voltage:

1. Cost of tower at place of erection	$266.00
2. Cost of erection of tower	30.00
3. Cost of tower site	10.00
4. Cost of foundation installed	175.00
5. Cost of location and inspection of support	13.00
6. Cost of insulators at location of tower	22.00
7. Cost of placing insulators and cable	10.00

Determination of the constants k_1, k_2 and k_3 of equation (**70**).

k_1 = should not be less than 30.

k_2 = sum of items 1, 2 and 3 divided by the square of the height of the point of support above the tower footing.

$$= \frac{266 + 30 + 10}{37^2} = 0.2235.$$

k_3 = sum of items 4, 5, 6 and 7,

$= 175 + 13 + 22 + 10 = 220.$

Hence,

$$\frac{k_3}{k_2} = \frac{220}{0.2235} = 984$$

Interpolating the curve $k_3 \div k_2 = 984$ on Fig. 4 and plotting the curve of critical catenaries for the specified cable in terms of $2x$ and c from column 3 of Table I and column 37 of Table III, respectively, the two curves are found to intersect at the point $2x = 605$, $c = 2730$.

Hence, the most economical tower spacing for the cable and climate specified in problem 3 is 605 ft. (184.4 m.).

It will be remembered from the analyses of the preceding sections that the catenary at the minimum temperature under the most severe weather conditions is expressed by

$$\text{max. } T \div w_1 = c_1 \cosh \frac{x}{c_1}$$

Digitized by Google

The maximum tension max. T is proportional to the size of the cable of a given material, whereas the weight per unit length w_1 is not directly proportional to the size of the cable since the ice and wind load included in the term w_1 does not vary in proportion to the size of the cable. It will be found, however, that the variation of the ratio max. $T \div w_1$ decreases as the size of the cable increases, and that it will be practically negligible for large cables such as are used for long transmission lines. The influence of temperature on the length of the span is independent of the size of cable and the influence on the catenary formed by the cable due to changes of average tension along the span is also practically independent of the size of cable, remembering that the catenary changes due to changes in tension are proportional to the ratio av. $T \div w$. Therefore, the critical catenary is practically independent of the size of cable, and the curve on Fig. 4 representing critical catenaries for a copper cable in a given locality will be approximately fixed in location for any size of cable used in long transmission lines.

Since the critical catenary is a function of the range of temperature for a given locality rather than a function of the magnitude of the maximum or minimum temperature, and since the extreme range of temperature does not vary greatly for different localities in spite of the fact that the maximum or minimum temperatures may greatly differ, the critical catenary will be but little influenced by the location of the span. Of course, this generalization does not embrace span designs for the tropics and climates exclusively controlled by the trade winds.

The most extraordinary fluctuations of transportation charges and market prices of labor and materials do not influence the ratio $k_3 \div k_2$ to a very great extent since these factors jointly affect all the cost items which make up the total cost of a line support. The sensitiveness of this ratio to the influence of changes in the size of the cable is also very small since both k_2 and k_3 are affected practically in the same proportion. In comparing the magnitude of the item covering insulator cost with the total cost of the support, it will be conceded that variations in this item also have little influence on the magnitude of the ratio.

From the above it follows that for a given cable material the range of variation of the most economical tower spacing is very small, no matter what might be the size of the cable or the location of the transmission line in climates other than tropical or

Digitized by Google

subtropical, or what might be the prices of commodities used in the make-up of the finished support.

Supposing a conservative estimate places the range of fluctuations of the ratio $k_3 \div k_2$ between the limits 800 and 1200, Fig. 4 will disclose the interesting fact that the most economical tower spacing for a copper cable, ranges between the narrow limits of 580 ft. (176.7 m.) and 630 ft. (192 m.) for a long transmission line.

The above analysis in connection with the curves of Fig. 4 will validate the statement that for a copper cable the most economical tower spacing is approximately 600 ft. (182.8 m.).

Digitized by Google

A lecture delivered at the Fifth Midwinter Convention of the American Institute of Electrical Engineers, New York, February 15, 1917

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

MODERN PHYSICS

BY R. A. MILLIKAN

MY POSITION tonight is somewhat reminiscent of a story that my father used to be fond of telling of a Scotch preacher who thought that all of the italicised words in the Holy Writ were meant to be emphasized, and so he read: "And Abraham said unto his servants, saddle me an ass, and they saddled *him*." When one of his parishioners expostulated with him and told him that he didn't think that was really what was meant, he, being a Scotchman, kept his own opinion, but being more or less politic, he said he would change it, and so the next time he read: "And Abraham said unto his servant, saddle *me* an ass, and they *saddled* him." (Laughter.)

The point of the story is that it doesn't make any difference where the emphasis is placed, the situation remains entirely unchanged. I am, however, really glad to be saddled tonight, because I should like to do a little bit, if I can, towards bridging the chasm which we have foolishly—I had almost said idiotically—allowed to grow up between the physicist and the applied physicist, who commonly is called an engineer. The chemists have been very much more sensible, they have not split up into two groups, called chemists and applied chemists, and there is absolutely no more reason why we should have done so, because obviously the physicist is merely the vanguard in the army of engineers, the scout, the explorer, who is given the task of trying to open up new paths for human progress, of prospecting for new leads to nature's gold, and it is just as important that the engineer know where he is and what he is doing as it is that he know where the army is which is behind and which supports him.

If you have any respect for my subject or any respect for me, you will not expect me to outline in the space of one brief hour the work of modern physics. It is utterly impossible to do, and I can say that without affecting an inordinate egotism. I had the good fortune to listen a little while ago to a series of lectures

Digitized by Google

by our honored ex-President, Mr. Taft, on "The Executive Power," and he said in those lectures that his friend, Mr. Roosevelt, had somewhere classified the Presidents of the United States into two groups, the first, the group that had interpreted the executive power broadly and exercised it largely, and the second, the group that had interpreted it narrowly and exercised it sparingly, and he said that he began the first group with Lincoln and closed it with himself, and that he began the second group with Buchanan and closed it with myself—that is, with Mr. Taft. Then, with his inimitable chuckle, Taft said, "That reminds me of a story about a little boy who came home from school and said, 'Papa, did you know I was the brightest student in class?' His father replied, 'No, I didn't know it. When did the teacher tell you so?'

"The boy answered, 'The teacher didn't tell me so, I just noticed it myself.' " (Laughter.)

If I appear at all in what I say to have just noticed it myself, I beg of you at any rate to believe me that the appreciation is an appreciation of the subject, of the method that it uses, of the spirit that underlies it, and of the results that have actually flowed from it, and not an appreciation of any individual or group of individuals.

The spirit of modern science is something relatively new in the world's history, and I want, as an introduction to the main address, to give an analysis of what it is. I want to take you up in an aeroplane which flies in time rather than in space, and look down with you upon the high peaks that distinguish the centuries, and let you and me see together what is the distinguishing characteristic of this century in which we live. I think there will be no question at all, if you get far enough out of it so that you can see the woods, without having your vision clouded by the proximity of the trees, that the thing which is characteristic of our modern civilization is the spirit of scientific research—a spirit which first grew up in the subject of physics, and has spread from that to all the other subjects of modern scientific inquiry.

That spirit has three elements. The first is a philosophy, the second is a method, and the third is a faith. Look first at the philosophy. I say that is new for the reason that all primitive peoples, and many that are not primitive, have held a philosophy that is both animastic and fatalistic. Every phenomenon which is at all unusual or for any reason not immed-

Digitized by Google

iately intelligible used to be attributed to the direct action of some invisible personal being. Witness the peopling of the woods and streams with spirits by the Greeks; the miracles and possession by demons of the Jews; the witchcraft manias of our own Puritan forefathers, only two or three hundred years ago.

Now, that a supine fatalism results from such a philosophy is to be expected, for according to it everything that happens is the will of the gods, or the will of some more powerful beings than ourselves. And so, in all the ancient world, and in much of the modern also, three blind fates sit down in dark and deep inferno and weave out the fates of men. Man himself is not a vital agent in the march of things, he is only a speck, an atom which is hurled hither and thither in the play of mysterious, titanic uncontrollable forces.

Now, the philosophy of physics, a philosophy which was held at first timidly, always tentatively, always as a mere working hypothesis, but yet held with ever increasing conviction from the time of Gallileo, when the experimental method may be said to have had its beginnings, clear up to the present time, is the exact antithesis of the above. Stated in its most sweeping form it holds that the universe is ultimately rationally intelligible, no matter how far from a complete comprehension of it we may now be or indeed may ever come to be. It believes in the absolute uniformity of nature. It views the world as a mechanism, every part and every movement of which fits in some definite, invariable way, into the other parts and the other movements; and it sets itself the inspiring task of studying every phenomenon in the confident hope that the connections between it and other phenomena can ultimately be found. It will have naught of caprice in nature. It looks askance at mysticism in all its forms whether put forth by Dionysus in Greece in 300 B. C. or by the devotees of Bergson in Paris in 1915. That is the spirit, the attitude, the working hypothesis of all modern science, and let me say that this philosophy is in no sense materialistic, because good, and mind, and soul, and moral values, which is only another word for God, these things are all here just as truly as are any physical objects, and with that kind of a creed they must simply be inside and not outside of this matchless mechanism.

Second, as to the method of science, it is a method practically unknown to the ancient world; for that world was essentially subjective in all its thinking and built up its views of things

Digitized by Google

largely by introspection. The scientific method on the other hand is a method which is completely objective. It is the method of the working hypothesis which is ready for the discard the very minute it fails to work. It is the method which believes in a minute, careful, wholly dispassionate analysis of a situation; and any physicist or engineer who allows the least trace of prejudice or preconception to enter into his study of a given problem violates the most sacred duty of his profession. This present cataclysm which has set the world back a thousand years in so many ways, has shown us the pitiful spectacle of scientists who have forgotten completely the scientific method, and have been controlled simply by prejudice and by preconception. This is no reflection on the scientific method, it merely means that these men have not been able to carry over the methods they use in their science into all the departments of their thinking. The world has been controlled by prejudice and emotionalism so long that reversions still occur, but the fact that these reversions occur after all does not discredit the scientist, or make him disbelieve in his method. Why? Simply because that method has worked, it is working today, and its promise of working tomorrow is larger than it has ever been before in the world's history. Do you realize that within the life time of men now living, within a hundred years, or one hundred and thirty years at most, all the external conditions under which man lives his life on this earth have been more completely revolutionized than during all the ages of recorded history which proceeded? My great grandfather lived essentially the same kind of a life, so far as external conditions were concerned, as did his Assyrian prototype six thousand years ago. He went as far as his own legs or the legs of his horse could carry him. He dug his ditch, he mowed his hay, he did all the operations of his industrial life, with the power of his own two arms, or the power of his wife's two arms, with an occasional lift from his horse or his ox. He carried a dried potato in his pocket to keep off rheumatism, and he worshiped his God in almost the same superstitious way. It was only in the beginning of the nineteenth century that the great discovery of the ages began to be borne in upon the consciousness of mankind through the work of a few patient, indefatigable men who had caught the spirit which Gallileo perhaps first notably embodied, and passed on to Newton, to Franklin, to Faraday, to Maxwell, and to the other great architects of the

Digitized by Google

modern scientific world in which we live,—the discovery that man is not a pawn in a game played by higher powers, that his external as well as his internal destiny is in his own hands. You may prefer to have me call that not a discovery but a faith. Very well! It is the faith of the scientist, and it is a faith which he will tell you has been justified by works. Take just this one illustration, suggested by the opening remarks of your President. In the mystical, fatalistic ages which preceded, electricity was simply the agent of inscrutable Providence; it was Elijah's fire from Heaven sent down to consume the enemies of Jehovah; or it was Jove's thunderbolt hurled by an angry God; and it was just as impious to study so direct a manifestation of God's power in the world as it would be for a child to study the strap with which he is being punished, or the mental attributes of the father who is behind the strap. It was only one hundred and fifty years ago that Franklin sent up his famous kite, and showed that these thunder bolts were identical with the sparks which he could draw on a winters night from his cat's back. Then, thirty years after that Volta found that he could manufacture these same thunderbolts artificially by dipping dissimilar metals into an acid. And, thirty years farther along Oersted found that those same thunderbolts when tamed and running noiselessly along a wire would deflect a magnet, and with that discovery the electric battery was born, and the erstwhile blustering thunderbolts were set the inglorious task of ringing house bells, primarily for the convenience of womankind. Then ten years later Faraday found that all he had to do to obtain a current was to move a wire across the pole of a magnet, and in that discovery the dynamo was born, and our modern electrical age, with its electric transmission of power, its electric lighting, its electric telephoning, electric toasting, electric foot warming electric milking,—all that is an immediate and inevitable consequence of that discovery—a discovery which grew out of the faith of a few physicists that the most mysterious, most capricious and the most terrible of natural phenomena is capable of a rational explanation and ultimately amenable to human control.

In that statement, I have revealed the top root of the civilization of the nineteenth century. Add to it a bit to cover the harnessing of steam, and the development of the principle of the conservation of energy, and you have an epitome of the progress of the nineteenth century. It all grew out of the application of a few, a relatively few, discoveries as to the way in which nature works.

Digitized by Google

And at the end of the nineteenth century there were many of us physicists and engineers who thought that all the great discoveries had been made. It was a common statement that this was so. I heard it publicly made in 1894, and yet within a year of that time I happened to be present in Berlin at the meeting of the Physical Society at which Roentgen showed his first photographs, and since that time we have had a whole new world, the very existence of which was undreamed of before, opened up to our astonished eyes. We have found a world of electrons which underlies the world of atoms and molecules with which we had been familiar, and the discoveries in that world have poured in so rapidly within the last twenty years that there are no two decades in human history that compare at all with them in the rapidity of the advance. And these discoveries have been made too for the most part by groups of men interested merely in finding out how nature works. They have been made almost exclusively by college professors; and for ten years they remained the exclusive property of these professors. What has happened in the last ten years? The industrial world has fallen over itself in the endeavor to get hold of these advances, and by their aid it has increased ten-fold the power of the telephone, it has obtained four or five times as much light as we got a few years ago out of a given amount of electrical power, it has developed new kinds of transformers the existence of which was never dreamed of before—all these things are coming *now*, it is not in the distant future, that we are going to find the applications; we have found in the last five years a great quantity of them, and how many more are going to come, no man can tell.

And yet we must not focus our attention too intently upon the utility of a discovery. Did you ever hear the story of what happened when Faraday was making before the Royal Society, in 1831 that experiment to which your Chairman referred. He performed his experiment, and then explained it. It was simple, it did not look particularly interesting. One saw only a deflection of a needle. And some woman in the audience said, "But Prof. Faraday, of what *use* is it?" His reply was, "Madam will you tell me of what use is a new born babe?"—and what a reply it was? Infinite possibilities—possibilities which may indeed not be realized, but at any rate something *altogether new*. Faraday did not care of what *immediate* use that new thing was, for he was one of the great souls who had caught the spirit of Gallileo. He knew that human progress depends primarily

Digitized by Google

upon *the growth of the human mind*, the ability of man to get hold of nature. The utilities might come, they always do come, but they generally crop out as by-products, and the man who has got his mind fixed merely on utilities is simply the man who kills the hen to get the golden egg. I have just as much respect for utilities as you or anybody has, I believe that nothing is worth while except as it contributes in the end to human progress, but the difficulty is you cannot tell, nor can I or anybody else tell what is going to contribute to human progress. The thing that is important is that the human mind should grow. That is the sine qua non of progress. At the Capitol in Harrisburgh there is a picture by Sir Edwin Abbey, which is entitled, "Wisdom, or the Spirit of Science." It consists of a female veiled figure with the forked lightnings in one hand, and in the other the owl and the serpent, the symbols of mystery; and beneath is the inscription,—

"I am what is, what hath been and what shall be.
My veil has been disclosed by none
What I have brought forth is this: The sun is born."

It is to lighten man's understanding, to illuminate his path through life, and not merely to make it easy, that science exists. Hence, if you ask me what are the utilities of the particular category of discoveries which I am going to run over here very rapidly, I may be able to tell you of a good many of them, but I shall not try to catalogue them all, because that is not where our immediate interest lies, It is "where there is no *vision*" That "the people perish."

Finally, before launching upon the sea of recent discovery, I wish to make one more remark about the method of science, namely this: The progress of science is almost never by the process of revolution. You see a great deal in your newspaper headings about revolutionary discoveries. They almost never happen. Thus when the atom was found not to be an ultimate but a divisible thing, there was no revolution, there was not a single law that had to be given up. We had simply opened up a new field, tapped a new lead, found an unexplored region, a sub-atomic region, and all that was above it remained just exactly as it had been, and no chemist had any occasion to be disturbed, for the chemists' laws were just as precise as they had been before. Sometimes we do indeed find that we have generalized too far, and that some law which we had supposed to be of universal application is limited in its

Digitized by Google

scope, but this does not alter the fact that the growth of science is in general by a process of accretion, almost never by that of revolution. Once in a while we have something revolutionary, but not often.

Let me now run over a list of ten discoveries which I will call the ten most important advances of the last twenty years. I will not keep you long upon them, I will just touch upon them, because I could spend the whole evening on any one of them.

We may aptly characterize the physics of the last twenty years as the physics of atomism, and the first discovery on my list of ten advances is the recent verification of the adumbrations of the Greeks regarding the atomic and the kinetic theories—the proof that, as Democritus had imagined 500 B. C., this world does indeed consist, in every part of it, of matter which is in violent motion.

Up to within six years there were not a few distinguished scientists who withheld their allegiance even from these atomic and kinetic theories of matter. The most illustrious of them was Professor Wilhelm Ostwald, but in the preface to a new edition of his *Outlines of Chemistry* he now says frankly:

"I am convinced that we have recently become possessed of experimental evidence of the discrete or grained nature of matter for which the atomic hypothesis sought in vain *for hundreds and thousands of years*. The isolation and counting of gaseous ions on the one hand. . . . and on the other the agreement of the Brownian movements with the kinetic hypothesis. . . . justify the most cautious scientist in now speaking of the experimental proof of the atomic theory of matter. The atomic hypothesis is thus raised to the position of scientifically well-founded theory."

I think you all know what the Brownian Movements are but I wish especially to call attention to the fact that this advance was made not by a practical man, but by a man who never did any experimental work in his life, Einstein, a mathematician, a man who was capable of analyzing a theory and predicting results, and the experimentalists have checked those results. The results consist in predicting how far a given particle that you can see in an ultra microscope will drift in a given time, and our own experiments have checked this prediction to within one-half per cent. It is that sort of evidence that has convinced Ostwald of the correctness of the kinetic and the atomic theories.

The second advance is the proof of the divisibility of the atom, a proof which grew out of the discovery of X-rays. Let me

Digitized by Google

tell you how. If you have here two plates with an electric field between them, and nothing else but a monatomic gas like helium, then it is found that when the field is thrown on the helium is perfectly stagnant, but when a beam of X-rays is shot between the plates some of the molecules become electrically charged and begin to jump, some of them toward the upper plate and some toward the lower plate, where their presence can be detected by an electrical measuring instrument. What does that show? It shows that the thing which we call an atom has electrical charges as its constitutents; and the history of the last twenty years in physics has consisted pretty largely in determining what are the properties of these electrical constituents.

The third is the discovery of radio-activity, which occurred just a little after the discovery of X-rays. And here again we found matter doing things we had never dreamed it was doing viz: shooting off from itself both negatively and positively charged particles, the negatives with a speed which may approach close to the velocity of light, 186,000 miles per second, and positives with a speed of one-tenth of that, or 18,000 miles. The fact that such speeds could be imparted to projectiles of any kind was undreamed of twenty years ago.

The fourth discovery that I wish to mention is the discovery of the atomicity of electricity, the proof that the thing we call electricity is built up out of a definite number of specks of electricity, all exactly alike, and that what we call an electrical current consists simply in the journey along the conductor of these electrical specks, which we may call with perfect justice definite *material* bodies. Now, I can give you in just a word the proof of that statement. There are half a dozen ways in which it could be approached. I will mention the one with which I am most familiar, because it is the particular proof which we worked out at our laboratory.

We took these plates with a field of 10,000 volts between them, with a little hole in the top plate, and we blew an oil spray above the top plate so as to get an electrically charged body just as small as we could, for we expected that the frictional process involved in blowing the spray would charge the drops, which it was found to do. We let one of those drops come into the space between the plates and then moved it up and down by an electrical field, throwing on the field as it came close to the bottom plate, and throwing it off as it approached the upper

Digitized by Google

one, and so we kept that oil drop going up and down between the plates, in the hope that it would capture some of the ions which we knew existed in the air, put there by radium or other agencies. The drop met our fullest expectations as a police officer capturing ions frequently and signalling the fact of each capture to the observer by the change in its speed in the field. For the oil drop is an electrically charged body, and in a given field it moves with a definite speed. If however it captures an ion, its charge increases or decreases, and hence its speed increases or decreases. If the charges on ions are all alike, then we can only get one particular change in speed. If the charge that is already upon it, put there by the frictional process, is built up out of these same units, then the total speed which the field will impart must be an exact multiple of the change in speed which the capture of an ion produces. In other words, if electricity is atomic in structure, you cannot get in a given field anything except a definite number of speeds, which will make an arithmetical series, that is, will come up by steps, one, two, three, etc. That is exactly what we found. We have experimented with thousands of drops and scores of different substances, and they always work exactly that way. Both positively and negatively charged drops are found to act in quite the same way, showing that both positive and negative electrical charges are built up of specks of electricity. Further we can count the number of those specks, which we will call electrons, in a given drop, with the same certainty with which you can count the number of fingers that are before you now. And again since Rowland showed that an electrical current is nothing but a charge in motion, you have here the proof that the electrical current that goes through these lamps, for example, is nothing except the motion of a certain number of electrical specks through or over the filament of the lamp. Add to that J. J. Thomson's discovery made in 1881, that an electrical charge possesses inertia, the only distinguishing property of matter, and you have made it perfectly legitimate to say that an electrical current in a wire is a definite, material, granular something which is moving along that wire.

The fifth great discovery of modern physics is the bringing forward of evidence for the electrical origin of mass. I have just said that electricity is material. Can we turn it around, and say that all matter is electrical in origin? The last is not exactly the same as the first, and it needs evidence. When we

Digitized by Google

have proved that an electrical charge possesses inertia or mass we have not shown that there is no inertia in matter which is not electrical in its origin? Now we have a certain amount of evidence upon this point and I wish to state what that evidence is. We can measure the inertia of the negative electron and it is found to be $\frac{1}{1845}$ of the inertia of a hydrogen atom, but the positive electron is never found with an inertia less than the inertia of a hydrogen atom. Let us consider the inertia of the negative. So long as it is moving slowly compared with the speed of light its inertia remains constant because the shape of its electromagnetic field is not appreciably distorted by its motion. But as soon as you imagine it to be moving with a speed which is close to the speed of light, that is with a speed which is nearly as great as the speed with which its own electromagnetic field can travel forward, then further change in speed will distort the field and hence change the inertia. In other words, the inertia of a charge ought to be a function of speed only when the speed approaches the speed of light. As a matter of fact, when it is from 0.1 up to 0.9 of the speed of light, you can compute just how it ought to vary. Now, by some happy chance the physicist has found negative electrons, namely those shot off by radium, which are going with these speeds, and hence it is possible to test our theory for these particles and see whether the rate of change of their inertia with the speed checks with the theoretical value. It is found that there is such a check. This means that there isn't any inertia in those particles which does not obey the electromagnetic laws. Therefore, we *have good reason for assuming that the negative electron is nothing but a disembodied electrical charge, and that its inertia is wholly of electrical origin.*

Now, with respect to the positive electron, we haven't that evidence as yet, but it is obviously in the interest of simplicity to assume one kind of inertia rather than two. Further, we have a little bit of evidence of this kind, and I wish to mention what it is, because that will furnish an introduction to my sixth important modern discovery. We have good reason to think, at any rate, that there is only one positive electron in the hydrogen atom, but that the mass, or inertia of that positive is almost the mass of the hydrogen atom—at any rate we never find it any less. Now if this inertia is all electrical then we know from theory that the charge must be more condensed in the positive than in the negative, consequently, if we are going to

Digitized by Google

make the observed inertia of the hydrogen nucleus all electrical, it must be even a more dense charge, that is a smaller body, than is the negative charge. So, we first get the picture by that kind of a theory of an atom which has an extraordinarily minute single positive nucleus, and negative electrons around the outside. We first got this picture by that kind of a theory, but we don't depend upon that theory now, because we know that the conclusion is correct. We know that the atom does consist of a body with a positive nucleus which is extraordinarily minute, and we can tell just how large it is, if we define the nucleus as the part of the atom that is impenetrable to the alpha rays of radium.

This brings me to the sixth of our discoveries namely *the discovery of the nucleus atom*. Let me give you just a brief statement of how we know that the atom is somewhat like a miniature solar system, with an extraordinarily minute nucleus, the size of the nucleus never being more than 1/100,000 part of the diameter of the atom, with a certain number of subsidiary bodies—negative electrons—which we should liken to the planets, somewhere around the outside. How do we know that is the case? We have this direct evidence. Nature takes a helium atom which is going with a speed of 18,000 miles per second, and nature shoots that atom right through a glass wall without leaving any hole behind, and without in any way interferring with the structure of the molecules of the glass. I can show you photographs that make the thing so clear that the wayfaring man can see it, you don't need to be a physicist. I will do so at the end of the hour, if there is time. This obviously means that the positive nucleus itself must be extraordinarily minute. Indeed the fact that the negative electron actually shoots through those hundreds of thousands of atoms without ever going near enough to any constituent of those atoms to knock any one of them out, and the fact that the positive nucleus of helium, viz; the alpha particle, shoots through even more molecules without being deflected at all from its course, causes one to wonder whether there was anything at all that is impenetrable in the atom. Why do we say there is a nucleus there? Because direct experiment says there is. There is a certain portion of the atom which the alpha particle itself cannot penetrate. If the impact is head on, the alpha particle goes right up to the atom and then it backs straight back again, or if it comes up to the atom at an angle like this it

Digitized by Google

goes off that way. (Illustrating.) It is only rarely that that happens, but Rutherford and Geiger and Marsden counted the percentage of alpha particles which goes straight on, and the percentage which goes off here, and in that manner, by perfectly simple algebraic analysis that any one of you can understand, without any assumption at all except the law of inverse squares, which can hardly be called an assumption, at least so far as the attraction between the positive nucleus and the negative electron is concerned we find how big that nucleus is. By the size of the nucleus I mean the size of that portion of the atom which is impenetrable to the alpha particles. It comes out something like 10^{-13} centimeters. The diameter of the atom is 10^{-8}. Furthermore, by counting how the deflections of the alpha particles are distributed around this sphere, which we can do directly with the aid of zinc sulphide spread over the inside of the sphere we can obtain the number of alpha particles deflected through any given angle, and then with a little analysis of unquestionable correctness, we find how many unit charges, positive electrons, there are in this exceedingly small nucleus, and it comes out approximately one-half of the atomic weight.

Now, I come to another extraordinary discovery which did not merely tell us approximately how many electrons there are in the nucleus but it told us *exactly* how many there are, and the result checked too with the number obtained by the foregoing approximate method. This brings me to the recent discoveries in the field of X-rays, and I will call the seventh of the modern advances the discovery of the nature of X-rays, which was virtually made by Barkla in 1904. For Barkla and others had proved that there are two types of X-rays, first, X-rays which consist in simple ether pulses pushed off from an electron when it changes its speed; and second so-called characteristic X-rays which are formed thus. When the electrons bump into a target they set something in the target into vibration, and this something sends off perfectly definite characteristic X-rays, which are like monochromatic light. So, we have two types of X-rays, pulse X-rays, like white light, and monochromatic X-rays, like monochromatic light, such as mercury gives rise to. That is the seventh of our great modern discoveries and it must be credited chiefly to Barkla.

The eighth I will call the discovery of crystal structure by the study of X-rays, which is due to Laue in Munich, and Bragg,

Digitized by Google

in England. The method is simply this. You know that we analyze light by a grating which consists of a series of equally spaced lines on a reflecting or transmitting surface. With such a device we can split light up into a spectrum but we cannot thus split it up unless the width of the grating space is comparable with the wave length of the light. In the case of X-rays, we had no knowledge of gratings whose grating spaces were anything like as small as the wave length of X-rays, in fact such gratings were unknown until Laue had the bright idea of using the regular arrangement of the atoms in a crystal for a grating to see whether that would not do the work, and it did the work marvelously well. It was found that we could compute the grating space of certain crystals from the density and the atomic weight and then from the observed spectrum find the wave length of X-rays. And now knowing the wave length we can work backward and find the grating-space for other crystals. We are now using this method for finding the positions and the arrangements of the atoms in crystalline bodies. Prof. Bragg in his recent book on X-rays and crystal structure has described this work very beautifully. Thus a whole new field of experimentation has been opened up and is being pursued in a great many laboratories, and with particular success by A. W. Hull at the laboratory of the General Electric Company. There are almost unlimited possibilities for the chemist in the discovery of the exact position of the atoms in any kind of crystal by this method.

But the results of this discovery as of most of the others which I have mentioned are rather insignificant when compared with those of the ninth which I am going to mention, namely the discovery of the relations between the elements, and the extension of our knowledge of the radiations emitted by different substances. This discovery was made by a young Englishman only twenty-six years old, Moseley, who has already, unfortunately, fallen a victim to this juggernaut which is at the present time crushing out the finest scientific brains in the world. Moseley was killed at the age of twenty seven a year after he made his epoch-making discovery, and all the lives and all the interests of the eternally infamous men who made this war are not to be compared in value to the world with a hair of Moseley's head. Yet he had to be sacrificed to save a threatened civilization. A double honor to Moseley.

His discovery was this: He was analyzing the characteristic X-rays which are given off when any kind of a substance is

Digitized by Google

bombarded with cathode rays. The experiment was in my judgment as brilliantly conceived, as carefully and skillfully carried out, and as illuminating in its results, as any which has been done in the last fifty years. What he found was this, that the atoms of all the different substances emit radiations or groups of radiations which are extraordinarily similar, but that these radiations differ as we go from substance to substance in their wave lengths. The whole discovery can be stated in this fashion: If you take the highest frequency emitted by a given atom, and if you lay down on a table a length which is equal to the square root of this frequency, and if on top of that you lay down the square root of the frequency of the atom which has the next lower frequency, and so if you continue to lay down, with one group of ends together, the measured square root frequencies of all the elements that you can study, then what have you got? You find that you have a flight of stairs, with perfectly definite equal treads; that is, the frequencies change by definite steps as you go from element to element. And there are only four vacant treads between the lightest element which Moseley could study, namely aluminum and the heaviest one, namely, lead, thus indicating that there are only four elements in this range which we have not already found. An extremely interesting question is, what is the greatest common divisor of this series of steps, that is, what is the top step? There are two ways to get at it. One is by filling all the spaces up to aluminum with known elements in the order of their weights—we cannot investigate the lighter ones by the X-ray method because their frequencies are too low; at least we have not yet found how to investigate them. Now there are just twelve elements below aluminum, so we may put them all in, starting with hydrogen. That would make hydrogen correspond to the top step. The second way is to find arithmetically the greatest common divisor of the square root frequencies. This gives us a frequency which is within a few per cent of the highest frequency which hydrogen can produce, according to Lyman's measurements in the ultraviolet region of optical radiations. This indicates again that hydrogen is the element corresponding to the first step. All of this seems to mean three things, it means first that the X-rays of hydrogen are just its ordinary visible radiations; second it means that Moseley opened up a whole new field of radiation, beginning with the radiations of hydrogen, and extending up to a frequency $(92)^2$ or 8464 times as high as

Digitized by Google

that given by hydrogen. I have squared 92 because 92 is the number of the step corresponding to uranium, the heaviest known element, and the one having the highest frequency in its characteristic X-rays. Moseley's discovery means in the third place, almost certainly, that the elements are built up one from another by successively adding the nucleus of the hydrogen atom. The probable reason for the change in frequency as the nucleus takes on a stronger and stronger charge is that the electron sending off say the highest characteristic frequency is in a stronger electrical field in the helium atom, for example, than in the hydrogen atom, and so as the charge on the nucleus goes up by successive steps in going from element to element frequencies go up by corresponding steps.

We may then picture with considerable confidence this whole physical world as built up out of one positive and one negative electron. The positive electron is the nucleus of the hydrogen atom. It is every minute in comparison with the negative, but much more massive, when two free positive electrons are tied together we have the helium atom. We don't know why these positives cling together. We can assume, as an hypothesis, that there are four positives in helium which are held together by two negatives, thus leaving but two free positions as experiment indicates is the case. The assumption here is that in the nucleus one negative is capable of holding two positives. This assumption would make the nucleus of any atom contain a number of negatives equal to the atomic number and a number of positions equal to twice the atomic number. So much for a very brief and incomplete sketch of Moseley's contribution to modern physics.

My last of the great discoveries of modern physics is one that I will just touch upon. It is the discovery of quantum relations in photo-electricity, in X-rays, and in optical spectra; but here I am coming to a field which we do not know very much about, which we do not yet understand, and my main motive in introducing it is to convince you that the physicist, in spite of all he knows, or thinks he knows, is a fairly modest fellow, because there are some things he knows he doesn't know, and one at present is the nature of radiation. However, we know some things about it that are new. For example, it is an extraordinarily interesting fact that when light of the X-ray type, or indeed, light of any frequency falls upon say a lithium or sodium surface, or upon almost any surface, it has the property in some

Digitized by Google

way of taking hold of a negative electron in the atoms of that surface and of hurling that electron out with a perfectly definite speed, which we can measure, and which we find to be exactly proportional to the frequency of the light. That is an extraordinary phenomenon, and it is one that we explain on a kind of quantum theory which I will not attempt to go into here, because of the fact that we have not yet worked it out fully, so that I cannot give you anything very definite about it; but at any rate, the quantum constant comes out of the photoelectric effect, as shown in my own work, out of X-ray work as discovered by Duane and Hunt at Harvard, and out of spectroscope work, as shown by Bohr in the beautiful theory of the atom which he has developed within the last three or four years.

I think I have brought you in this brief survey to the very outmost boundaries of our present knowledge. Bring me back ten years from now, and we will know more about these quantum theories; but for the present I will stop, and close this hasty survey of the problems and successes of modern physics with a few reflections which are based upon historical studies.

At the University of Chicago I have a friend by the name of Braested, who is an Egyptologist. Braested tells me that he and his fellow Egyptologists have proof that less than 100 years elapsed from the time when, about five thousand years ago, the Egyptians knew so little about building that the best they could do was to pile crude rows of uncut stone around their dead, to the time when some of the great pyramids were built, structures which represent in some ways the height of the builder's art, structures on which the surfacing is so perfect that huge granite blocks eighteen feet on a side are joined together without cement and with not as much 1/100 of an inch of space anywhere between them. That kind of engineering we do not do now, luckily we do not have to do it, but it is doubtful if we could do it if we would. I am mentioning this to bring out the fact that Egypt, at that time, got the key to a certain kind of development, and pushed that development to a marvelous degree of perfection. Indeed there was in that century, so Professor Braested says, an industrial progress which has never been equalled at any time in the world's history until within the last one hundred years, when the modern industrial revolution set in.

Go now to Greek history, and we find the same sort of a situation. About 500 B. C. the Greeks got the key to a certain

Digitized by Google

type of progress, and they developed a civilization which on the intellectual side, and on the artistic and aesthetic side, has never been equalled. The Greeks, like the Egyptians, got the key to a certain kind of civilization and they worked it out to marvelous perfection; but in neither case did these men or these races go on; they did not open up new fields; they did not tap new mines. Their civilization came to an apex, and then decayed, and the question has often arisen in your minds, as it has in mine, is this age in which we are living going to follow in the same way? Have we risen to a maximum? Have we had a period of marvelous development which is going to be followed by one of decay and stagnation, or are we going to ascend to higher and higher levels? No man can answer that question, but this I know and this you know, that it was wholly unnecessary that Greek civilization, or that Egyptian civilization should stop when it did. If they had developed the modern scientific spirit, the spirit of search for new phenomena and new methods, they could have found them. There were plenty of new mines for them to tap, plenty of unexplored fields to search out. But they did not do it. As for us I feel just as sure as Shakespeare did that "there are still more things in heaven and earth than are dreamed of in our philosophy," and if we stop, it will be because we have forgotten the lesson which Gallileo first tried to teach, and which we have been learning in the last one hundred years, and that is the lesson of research. It is the lesson, the philosophy, the method and the faith of modern physics. That is our hope, and if we keep that, if we don't call in our scouts because the rewards are larger in the applications, then I haven't any doubt that our civilization will go on; and if we do call in our scouts here in this country, then our civilization will give place to that of some other country which does not do so, but which learns the value for the human race of the spirit of modern scientific research.

Digitized by Google

Presented by Publication only.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

DESIGN CONSTRUCTION AND TESTS OF AN ARTIFICIAL POWER TRANSMISSION LINE FOR THE TELLURIDE POWER COMPANY OF PROVO, UTAH

BY GEORGE H. GRAY

ABSTRACT OF PAPER

A description is given of an artificial power-transmission line which duplicates, in considerable detail, an actual transmission system. Each unit of the artificial line represents about ten miles of the actual line.

Methods are given of calculating the correct distribution of inductance between self and mutual, and of calculating the correct distribution of capacity between wire and wire, and wire and ground.

It is shown that this artificial system will duplicate very closely, even under extreme conditions of short circuits and grounds, many of the phenomena occurring on the actual system.

A description is given of some oscillographic tests, made on this line, of the magnitudes and phase relations of current and voltage at different points, when the line was subjected to various types of short circuits and grounds.

The data are presented in the form of vector diagrams; one for each point of the line where readings were taken. In addition to the diagrams, arrow-headed lines are shown at each station. These indicate the magnitudes and directions of power flow for each phase (as shown by star-connected wattmeters) and the total power flow.

It is shown that the total power flow is not always toward the short circuit (or ground). Hence, two-wattmeter principle relays will not always indicate toward the short circuit (or ground) and may sometimes operate the wrong switch.

With a three-phase short circuit the direction of power flow for each phase, and consequently the direction of total power flow, is always toward the short circuit.

With a two-wire short circuit, if the phase rotation is $A - B - C$, and the short circuit is between wires B and C the power flow indication of the B phase wattmeter is, at all stations, toward the short circuit. The wattmeters for the other phases may indicate away from the short circuit.

A ground on a single wire does not appreciably alter the power flow indication of any of the wattmeters, if the neutral is ungrounded.

If the neutral is grounded, the power flow indication for the grounded phase is toward the ground at all points.

If two wires are grounded at the same time, with the neutral grounded, the power flow indications are practically the same as for the two-wire short circuit.

INTRODUCTION

There are three ways in which an experimental study of problems connected with power transmission systems may be made:

NOTE: Written discussion of this paper is invited.

Digitized by Google

first, by using the actual system; second, using an experimental line; and third, using an artificial line. By an "expermental line" is meant a short length of line of the same type of construction as the actual system. By an "artificial line" is meant one in which the constants of the actual system are obtained by means of inductances, resistances and condensers, usually lumped at frequent intervals.

The actual system would appear at first glance, to be the best place to conduct experiments, but it has certain disadvantages. In most cases it must be out of commercial service while the tests are being conducted; it is almost impossible to make simultaneous observations at different parts of the system: in case anything goes wrong there is a chance that expensive apparatus may be damaged; and lastly, there is always the possibility that a switch which is supposed to be closed may be open, and vice versa.

An experimental line is useful for studying the behavior of insulators, corona losses and similar problems, but is of no value for studying surges, voltage drop, or any problem which requires a long line.

The artificial line, however, has none of these drawbacks, and for most purposes seems to be the best of the three. Its greatest disadvantage is that, in order not to expend any great amount of power in the line, the voltage must be kept low. This eliminates the studying of such problems as corona losses, disturbances resulting from arc characteristics, etc. The following tables show the relations existing between the different quantities when a 40 kilovolt system is represented by an artificial system operating at 1000 volts:

	Kilovolts	Amperes	Kilowatts
Actual.....	40	100	20,000
Artificial.....	1	2.5	12.5

Because of their many advantages, several artificial systems have been constructed during the last few years. Most of them, however, have been built by engineering schools which, naturally, have not been interested in duplicating any particular system. Each artificial line, therefore, has been uniform throughout its entire length and has been built to represent a single line (or two parallel lines) of some standard type of construction.

The line described here is of a different character, and is, it is believed, the only artificial system which duplicates the whole, or the greater part of, an actual system. The line was built

Digitized by Google

about six years ago by the Telluride Power Company (now a part of the Utah Power & Light Co.); a hydroelectric concern which operated, at that time (besides other divisions), about 500 miles of 44-kv. transmission line in northern Utah. This whole

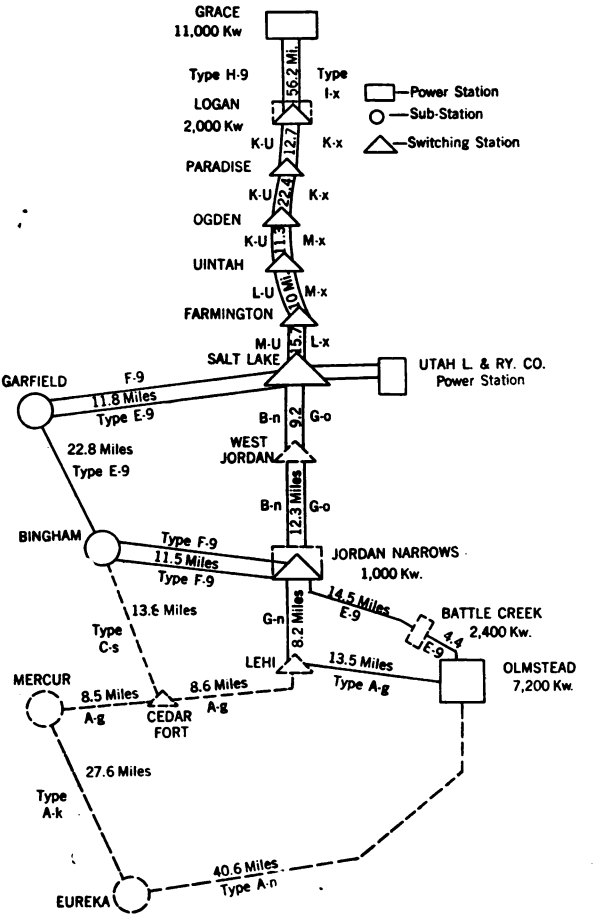


FIG. 1

Utah division, with the exception of one unimportant loop, was duplicated in the artificial system.

The artificial line was originally planned in 1908 by Mr. Edward Bennett (now Professor of Electrical Engineering in the University of Wisconsin). His original plans and computations were used later by Mr. L. N. Crichton and the author, who took

Digitized by Google

up the work and completed the line during 1911, after making quite extensive additions to the plans.

The line was built mainly with the idea of using it to study the operation of some sectionalizing relays which were being developed by the company. These tests, however, are the subject of another paper being prepared by Mr. Crichton, and hence will

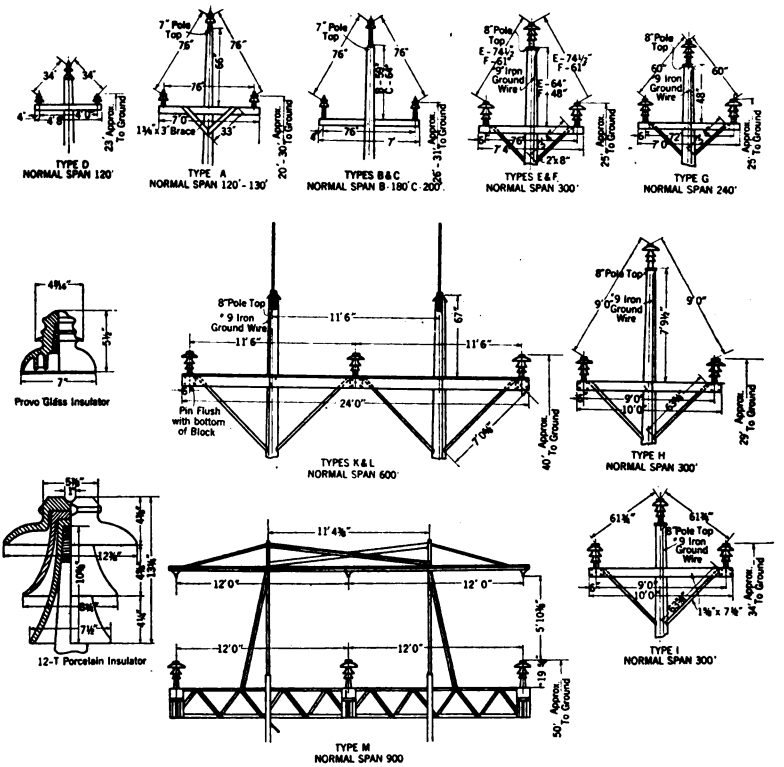


FIG. 2—TYPES OF 40,000-VOLT LINE CONSTRUCTION—THE TELLURIDE POWER COMPANY

not be treated here. Only the details of the line and some tests in which the relays were not used will be discussed.

The general layout of the Utah division of the Telluride Power Company in 1911 is shown by Fig. 1. The total generating capacity was a little under 24,000 kw., most of which was at the two ends of the system (11,000 kw. at Grace and 7,200 kw. at Olmsted). The load averaged about 14,000 kw. The total length of the lines was a little over 500 miles, covering about 340

Digitized by Google

Digitized by Google

miles
sented
In
lines
will b
the
City
Bing
Bing
field
at
of
2

miles of right of way. About 410 of the 500 miles were represented in the artificial system.

In Fig. 1 the duplicated part of the system is shown in full lines and the balance in dotted lines. The duplicated part, as will be seen, consisted of the Grace and Olmsted power stations, the parallel trunks from Grace to Olmsted through Salt Lake City (about 160 miles), the loop from Jordan Narrows through Bingham and Garfield to Salt Lake City (double except between Bingham and Garfield), the substations at Bingham and Garfield and the connection with the Utah Light & Railway Company at Salt Lake City. The lengths of the lines, the size and spacing of conductors, and other such data are given in Table I. Fig. 2 shows the different types of line construction.

DESIGN AND CONSTRUCTION

Transmission Line

The features of the transmission line which must be duplicated or approximated are:

Distributed inductance and capacity.
Leakage currents.
Electromagnetic coupling of phases.
Electrostatic coupling of phases.
Resistance of line conductors.

Distributed Inductance and Capacity. The most feasible way in which the large inductance and capacity of the transmission line may be obtained within the limits of an ordinary room is by the use of coils of wire and plate condensers. This, of course, does not result in distributed constants, but it has been shown that, for the frequencies used for the transmission of power and for the harmonics ordinarily encountered with those frequencies, an artificial line constructed with the capacities lumped at frequent intervals represents, to a very close degree of approximation, the actual line.

For example, if the spacing is such that there are ten condensers per wave length, most of the phenomena will be duplicated within 1 per cent. Since the ordinary 60-cycle power-transmission line has a wave length of about 3000 miles miles, a spacing of 300 miles is allowable. Even for the ninth harmonic the spacing may be as great as 33 miles without serious error. As this artificial line was composed of units, each representing only about ten miles of transmission line, errors due to lumping may be considered negligible.

Digitized by Google

Each unit consisted of three air-core inductance coils, electromagnetically interlinked, to represent inductive effects, with condensers connected between the coils, and also between each coil and ground, to represent capacity effects. In addition, resistance wire was used in series with each coil to represent the line resistance.

Leakage Currents. The resistance between each line wire and ground on the actual system was found to be of the order of 300 megohms per mile under average conditions. On a 40-kv. system, 500 miles long, having a peak load of 14,000 kw. and current per wire of 250 amperes, this means a total leakage current of only 0.038 amperes per wire, and a total watt expenditure of only about three kilowatts. These are negligible quantities and no attempt was made to approximate them on the artificial system. The resistance of the condensers from line to ground was about 300 megohms per ten-mile unit, or 3000 megohms per mile, when cold.

Electromagnetic Coupling of Phases. When the three conductors of a three-phase line are arranged at the vertices of an equilateral triangle, and the currents in the three phases are balanced, the sum of the currents in any two wires is equal to the current in the third wire, and flows in the opposite direction. Therefore, the only magnetic flux which is effective in producing the inductance of any wire is the flux due to the current in that wire and which lies between it and the other two wires. This flux, in absolute units, is

$$2\,I\,l\left(\log_e \frac{d}{r} - \frac{1}{4}\right) \qquad (1)$$

in which l = length of wire in centimeters.
d = distance between conductors.
r = radius of conductor.
I = current in absolute units.

The usual practise in line calculations is to consider this magnetic flux as causing the self inductance of the wire, thus eliminating the mutual inductance between wires or phases, from the calculations; in which case the self-inductance of each wire, to neutral, is

$$L = 2\,l\left(\log_e \frac{d}{r} - \frac{1}{4}\right) \qquad (2)$$

Digitized by Google

If the system were always balanced, it would be satisfactory to represent the three line wires in the artificial system by three separate coils, each having a self-inductance as determined above and arranged so as to have no mutual effects upon each other. It is evident, however, that such an artificial line would fail to represent unbalanced conditions. For instance, if the artificial system were operated with grounded neutrals and a heavy short circuit should occur between one wire and neutral, it would have no effect upon the voltage between the other wires and neutral; whereas, owing to the mutual inductance between conductors on the actual system, this voltage should be affected.

It seemed advisable, therefore, to use coils having the correct inductance to represent the self-inductance of the wires, and to arrange these coils so that the correct mutual effects would be obtained between them. This necessitated the determination of the actual distribution of self and mutual inductance.

A method of doing this, which seemed at first to have some merit, was to use the formula* for the self-inductance of a single straight conductor. This formula is

$$L_S = 2l\left(\log_e \frac{2l}{r} - \frac{3}{4}\right) \qquad (3)$$

The corresponding formula for mutual inductance is

$$L_M = 2l\left(\log_e \frac{2l}{d} - 1\right). \qquad (4)$$

where l, d and r have the same significance as in formula (**1**). However, in the derivation of formula (**4**) all of the flux, due to wire 1, between d and infinity, is considered to be effective in producing the mutual inductance; while, in the actual system, in a case like the one cited above (with the grounded wire) only the flux between d and the path of the current in the ground would be effective. Another objection to this method was that a large amount of copper would be required to produce the large self-inductance. As mutual inductive effects were to play, at most, only a small part in the operation of the line, it did not seem wise to go to this extra expenditure for copper.

Hence it was decided to approximate, as closely as possible, the

*See Bulletin of the Bureau of Standards, Vol. IV, page 301. "The Self and Mutual Inductances of Linear Conductors," by E. B. Rosa.

Digitized by Google

distance from the wire to the path of the return current in the ground. The accurate calculation of this distance was an almost impossible problem because of the unknown and variable resistances of the different layers of soil. Fifty feet was finally selected as this distance, and all of the calculations of self-inductance and mutual inductance were made on the assumption that the three wires had a common return, located fifty feet from the conductors.

The self-inductance of each wire was then found from the formula

$$L_S = 2l\left(\log_e \frac{50 \times 12}{r} + \frac{1}{4}\right)$$

and the mutual inductance from:

$$L_M = 2l\left(\log_e \frac{50 \times 12}{d}\right)$$

The values given by these three methods for ten mile sections (the average length of the sections used) of No. 2 solid copper, spaced nine feet on a side, are given in the following table.

	Inductance of 10 miles. (10^{-2} henrys)		
	L_S	L_M	$L_S - L_M$
Neglecting mutual inductance..	2.25	0.00	2.25
Return at infinite distance.....	4.95	2.70	2.25
Return 50 feet from wires.....	2.80	0.55	2.25

The resulting inductance for balanced conditions is seen to be the same, regardless of the method used, but the other values vary widely in the different methods. The first and second methods may be considered as setting lower and upper limits, respectively, for the self and mutual inductances. The true values lie somewhere between and probably not very far from those given by the third method.

Reducing these formulas (assuming the return 50 feet away) to practical units, we obtain, (for the inductance of each wire to neutral)

$$L_S = 0.322 \times 10^{-3}\left(2.303 \log_{10} \frac{50 \times 12}{r} + \frac{1}{4}\right) \text{ henrys per mile.}$$

and

$$L_M = 0.742 \times 10^{-3} \log_{10} \frac{50 \times 12}{d} \text{ henrys per mile.}$$

Digitized by Google

From these formulas the self and mutual inductances were calculated for each different type of construction. These values are given in Table I, in the column headed "Constants per Mile, Calculated".

In calculating the inductance and capacity for the stranded wires, a value midway between the diameter of the stranded wire and that of a solid wire having the same cross section was used for the diameter. This is the value given in Table I in the column headed "Equivalent Diameter".

The line was divided into sections, each approximately ten miles in length. The values for the self and mutual inductances of each of these sections are given in Table I, under the heading "Constants per Section".

In proportioning the coils, Stefen's Formula* for the self-inductance of coils was used, and the measured values of the self-inductance were found to agree with the computed values to about one half of one per cent.

The coils were made about six inches in mean diameter, and were wound with No. 17 double-cotton-covered copper wire. The number of turns varied from 360 to 435. A further means of adjustment was provided by bringing out several taps on each coil. The coils were wrapped with one layer of half-lap lin-o-tape, but were not shellacked.

The three coils to represent one section were then mounted in a wooden frame, as shown in Figs. 5 and 6. The correct self-inductance was obtained by means of the taps referred to. The correct mutual inductance between "side wires" was obtained by adjusting the coils in the horizontal slots; and that between the "center wire" and the "side wire" by adjusting the center coil in the vertical slot.

The range of inductance is illustrated by the values given in Table II for a few of the coils.

Tests showed that the coils could carry 2.2 amperes continuously with a 40 degree rise, and that 3.5 amperes could be carried for 15 minutes without dangerous heating. This current (3.5 amperes), at 1000 volts, corresponds to a current on the 44-kv. system of 154 amperes, which was never exceeded for any length of time.

Electrostatic Coupling of Phases. The only arrangement

*Bulletin of the Bureau of Standards, Vol. 5 No. 1. "Formulas and Tables for the Calculation of Mutual and Self Inductances of Coils" by Rosa and Cohn.

Digitized by Google

which will exactly represent, under all conditions, the capacity effects between the wires of a transmission system and ground, is the exact geometrical equivalent, on a small scale, of the line and earth immersed in a dielectric of very high inductive capacity. To keep such a line down to a reasonable length, a dielectric would be needed having a specific inductive capacity of 5000 or more. No such dielectric exists, so an arrangement was adopted in which properly proportioned plate condensers were connected between the conductors, and between conductors and

TABLE II.

Coil data. Inductance in 10^{-2} henries.

Inst. No.	Coil No.	L_1	L_2	L_3	L_4	L_5	L_6	R_6
	15	2.57	2.61	2.66	2.71	2.78	2.83	3.04
53	44	2.57	2.61	2.66	2.71	2.78	2.83	3.13
	61	2.56	2.61	2.66	2.71	2.78	2.83	3.14
	47	2.56	2.60	2.65	2.70	2.76	2.84	3.06
54	65	2.58	2.61	2.66	2.70	2.76	2.83	3.19
	64	2.56	2.60	2.65	2.70	2.76	2.84	3.18
	128	2.83	2.89	2.95	2.99	3.06	3.17	3.29
55	129	2.85	2.90	2.96	3.00	3.07	3.17	3.29
	131	2.83	2.88	2.94	2.98	3.05	3.15	3.28
	114	3.00	3.05	3.11	3.15	3.22	3.31	3.43
56	111	3.01	3.07	3.14	3.18	3.25	3.36	3.43
	113	2.97	3.02	3.09	3.12	3.20	3.30	3.43
	117	2.93	3.00	3.06	3.10	3.18	3.29	3.42
57	112	2.95	3.01	3.07	....	3.19	3.29	3.47
	115	2.95	3.02	3.08	3.12	3.20	3.30	3.40
	120	2.78	2.83	2.89	2.93	3.01	3.12	3.41
58	121	2.78	2.83	2.89	2.93	3.01	3.11	3.40
	126	2.81	2.87	2.94	2.98	3.05	3.15	3.41

ground, as shown in Fig. 3A. This arrangement, as will be seen later, approximates very closely the true distribution of capacity.

The capacities of these condensers were calculated as follows:

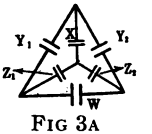


FIG 3A

Since the earth may be treated as an infinite equipotential plane, the actual transmission system (consisting of the earth's surface, conductors and ground wires) is the exact duplicate of the upper half of the electrical distribution which would be found between the actual conductors, with their charges, and the images of those charges with reference to the earth's surface.

Digitized by Google

Replacing the equipotential plane, then, by the images of the conductors and their charges, the potential above ground of any wire (say No. 1) is found to be

$$V_1 = 2q_1 \log_e \frac{D_1}{r_1} + 2q_2 \log_e \frac{D_2}{d_2} + 2q_3 \log_e \frac{D_3}{d_3} + \ldots\ldots$$

in which there is one term for each wire. q_1, q_2, q_3, etc. represent the quantities per unit length on the various conductors. r_1 is the radius of wire No. 1. D_1, D_2, D_3, etc. are the distances from conductor No. 1 to the images, and d_1, d_2, d_3, etc. are the distances from No. 1 to the other conductors. (For the derivation of this formula, see Appendix A).

By obtaining as many of these equations as there are unknown quantities q, solving for the q's, the quantity q on any conductor (and its phase relation) can finally be expressed in terms of the potentials of the conductors.

These calculations were made for wires No. 1 and No. 2, with the system ungrounded and for wire No. 1 with the center wire grounded, assuming the voltages to remain balanced in both cases.

Letting x, y, z and w represent the values of the capacities (connected as shown in Fig. 3A) the displacements CV across the three condensers connected to one wire were added (vectorially) and the sum put equal to the quantity q_1 or q_2 found by calculation for that wire. From these equations the values for the condensers x, y, z, and w were easily found.

These condenser values were calculated for each different type of construction, and are given in Table I, under the heading "Constants per Mile, Calculated". The complete set of calculations for one type is given in Appendix B.

The following values are taken from the calculations in Appendix B. They represent, in 10^{-8} coulombs, the quantities on the different conductors per mile; assuming that the voltages to ground are: $A \sin \alpha$, $A \sin (\alpha - 120 \text{ deg.})$, and $A \sin (\alpha - 240 \text{ deg.})$, for the three conductors.

Left	$1.339\, A \sin (\alpha + 0.55 \text{ deg.})$
Center	$1.316\, A \sin (\alpha - 120 \text{ deg.})$
Right	$1.339\, A \sin (\alpha - 240.55 \text{ deg.})$

Since the potential of the left conductor to ground is $A \sin \alpha$ and that of the center conductor $A \sin (\alpha - 120 \text{ deg.})$, the

Digitized by Google

capacities of these conductors are seen to be 1.339 and 1.316 $\times 10^{-8}$ farads per mile. The usual formula, $C = \frac{l}{2 \log_e \frac{d}{r}}$, gives the capacity as 1.329×10^{-8} farads per mile. This is between the true values given above. (1.339 and 1.316), and is very nearly equal to the average of the capacities of the three conductors.

How closely this artificial arrangement approximates the actual conditions is seen by considering several extreme cases. For example, if both outside conductors are earthed, the capacity of the center conductor to earth is 1.112×10^{-8} farads. In the artificial system it is 1.112×10^{-8}. If all three conductors are

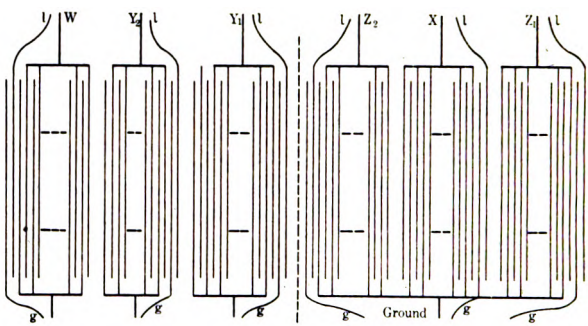


FIG. 3—CONSTRUCTION OF CONDENSERS X, Z_1, Z_2, W, Y_1, Y_2 CONNECTED AS SHOWN TO LEFT— l AND g REPRESENT EXTRA PLATES USED IN ADJUSTING

connected together, their capacity to earth is 2.209×10^{-8} farads. In the artificial system it is 2.204×10^{-8}. The capacity of the right conductor to earth, the other two being insulated, is 1.058. The artificial system gives 1.059. For the center conductor the values are 1.023 and 1.024.

The condensers consisted of lead foil plates, separated by three thicknesses of ordinary letter paper (Colorado Bond.) Extra sheets were added between the different groups and a $\frac{1}{2}$ in. pine board was used between the line-to-line and the line-to-ground groups.

The plates were of 0.0015-in. lead foil, each 4 in. by 8 in., with a tab for connecting alternate plates together. A few plates were left unconnected at the end of each group, to be used in adjusting the condenser to the correct value.

Digitized by Google

Each condenser was tested at 2000 volts for one minute. They will operate continuously at 1000 volts, 60 cycles, without dangerous heating.

Fig. 3 shows, diagrammatically, the construction of the condensers.

The capacity of each group of plates and the possible adjust-

TABLE III.

Condenser data. Capacities in 10^{-6} farads

Cond. No.	56	57	58	59	60
With stand number.	36	27	52	26	40
Z_1	8.01	6.66	6.76	7.09	7.86
$Z_1 + g$	8.01	6.88	6.76	7.37	8.10
$Z_1 + g + 1$	8.68	7.11	7.36	7.57	8.34
$Z_1 + 1$	8.33	6.66	6.91	7.09	7.86
X	7.85	6.55	6.34	6.41	7.12
$X + g$	7.85	6.55	6.34	6.41	7.27
$X + g + 1$	8.55	7.05	6.91	6.98	7.53
$X + 1$	8.29	6.90	6.71	6.80	7.21
Z_2	8.68	6.78	6.71	6.80	7.65
$Z_2 + g$	8.68	7.02	7.06	7.09	7.86
$Z_2 + g + 1$	9.30	7.29	7.30	7.34	8.08
$Z_2 + 1$	9.01	6.78	6.71	6.80	7.65
Y_1	1.84	1.84	1.83	1.98	1.89
$Y_1 + g$	1.95	1.84	1.83	1.98	1.97
$Y_1 + g + 1$	2.19	2.30	2.31	2.52	2.21
$Y_1 + 1$	1.84	2.10	2.04	2.28	1.89
Y_2	2.15	1.84	1.89	2.02	1.82
$Y_2 + g$	2.25	2.07	2.14	2.32	1.92
$Y_2 + g + 1$	2.62	2.22	2.28	2.43	2.14
$Y_2 + 1$	2.36	1.84	1.89	2.02	1.82
W	0.62	1.67	1.89	1.74	0.60
$W + g$	0.86	1.89	1.89	1.74	0.81
$W + g + 1$	1.08	2.07	2.45	2.28	1.04
$W + 1$	0.62	1.67	2.18	2.02	0.60

ment obtainable with the extra end plates, is shown by Table III for a few of the condenser units.

Resistance of Line Conductors. The resistance of the inductance coils was approximately three ohms, or 0.3 ohm per mile. Therefore, by connecting an additional resistance in series with the coils, any conductor up to, and including number 000 copper could be represented. This was larger than any in use on the

Digitized by Google

system. These external resistances were made of such a value that the combined resistance of the coil and external resistance, when carrying normal current, was equal to the resistance of the corresponding section of the actual line at the average temperture, 20 deg. cent.

The external resistances were of No. 18 Nichrome wire, wound in the form of spiral springs about $\frac{5}{8}$ in. in diameter. Each coil was connected between a binding post of the coil-stands and the correct tap of an inductance coil, as shown in Fig. 5.

These coils, or "spirals," were found to have only a very small inductance, (less than the difference between adjacent taps of the coils) so that their effect on the inductance was negligible.

The resistances of the inductance coils shown in Table II are given in the column headed R_6. These are the total resistances, at 20 deg. cent, not the resistance of the particular tap which was used. Table I, column headed "External Resistance, (Approx.)" shows approximately the amount of resistance required per line wire per section. This is only an average value, since the resistance of the different coils in the same section was found to be different.

Assembly of Line. Fig. 5 shows the method of assembling the units. The condensers were tapped in between the resistance and the inductance of each unit, and placed to one side of the coil-stands.

Tests were made to determine the mutual inductance between units, and also the effect on the inductance of the iron straps with which the condensers were bound. Both of these were found to be negligible.

The boards shown between tiers were inserted in order to facilitate the removal of any unit for repairs or alterations.

TRANSFORMERS

The artificial system was operated at about 1000 volts from the 230-volt, three-phase, 60-cycle, laboratory mains, by means of two banks of step-up transformers; one connected to the Grace and the other to the Olmsted station of the artificial system. Step-down transformers were used at the three substations and at the Salt Lake station two V-connected potential transformers were also used.

The actual transformers were connected Δ-Y at Grace and Salt Lake and Δ-Δ at Olmsted. As only one three-phase source was available for the artificial system, these two different connections

Digitized by Google

could not be used. The Olmsted transformers were, therefore, connected Δ-Y, to correspond with the connections at the other two stations. Taps were provided at the proper points on the high-tension side to adapt them to Δ-Δ operation, in case a second supply should become available. Additional taps were provided on the low-tension side of all transformers.

Two series transformers were used in the lines of the artificial system at each of the three substations, to supply current to the relays.

Generators

The generators were, as stated before, the supply mains of the laboratory. It was thought advisable, however, to provide a gradual decrease in the short-circuit current, similar to that brought about in the actual system by the demagnetizing action of the short-circuit currents on the generator fields. To accomplish this, the "artificial generators" shown in Fig. 5 were constructed, and connected to the system at Grace and Olmsted and at the Salt Lake substation. Each generator consisted of three coils, one in series with each line-wire. An iron core was held by a spring above each coil and with its end just entering the coil. When the line current became excessive, the core was pulled into the coil, thus considerably decreasing the current. The desired rate of decrease was obtained by means of the dashpots shown. When the disturbance was removed the core returned automatically to its former position.

Load

The loads at Bingham and Garfield were taken care of by the shop motors in combination with some carbon lamps. A power factor and load at each place equivalent to those on the actual system could thus be obtained.

The situation at the Salt Lake substation was rather peculiar. The Utah Light and Railway Company bought considerable power at that point, but also ran their generators in parallel with those of the Telluride system. Thus, under short-circuit conditions, power would sometimes flow back into the system. This situation was met in the artificial system by raising the voltage on the low-tension side of the Salt Lake transformers and connecting them to the supply mains. Thus power was made to circulate around the system, coming in at the Grace and Olmsted stations and flowing out at Salt Lake. Wattmeter measurements

Digitized by Google

made during one of the tests showed a load of 2.1 kw. at Salt Lake with only 0.3 kw. coming from the laboratory mains. Of course, with a short circuit near the substation, the direction of power flow was reversed.

Switchboard

The artificial system was controlled almost entirely by means of the switchboard shown in Figs. 4 and 5. On the front of this board was painted a map of the system, giving the location of each switch, power station, substation, etc. The high-tension windings of the transformers and the ends of the transmission line sections were brought to their proper places on the back of this board, terminating in small, spring clips. The switches were of the plug type and consisted of wooden blocks with three spikes driven into each. By inserting these from the front of the board the desired clips could be connected together behind the board. All high tension was thus kept behind the board, which made the operation of the line much safer. A hole drilled into each spike, where it entered the wooden block made possible the insertion of plugs (attached to lamp cord) for obtaining the voltage at any desired point. To obtain the current, plugs with split tips were used. Thus, instead of passing directly from clip to clip through the plug the current could be led out through an ammeter and back to the other side of the plug tip. The same two types of plugs were used for obtaining current and voltage for oscillograph work. Shelves, as shown in Fig. 4, could be readily attached to the board, for holding meters or other apparatus.

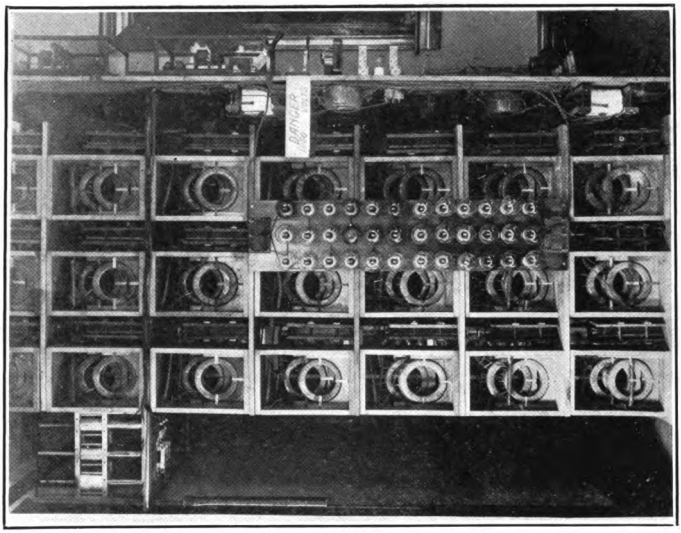
All of the wiring behind the board was done with No. 19 three-conductor telephone wire, having red, yellow, and green tracers. As the corresponding wires on the front of the board were painted the same colors, any trouble could be traced very easily.

The neutrals of all of the condensers were connected together, and used as the ground of the system.

Pilot lamps and ammeters were placed in the low-tension side at each station, to indicate, roughly, the load and voltage conditions.

In Fig. 4 a three-pole switch, with three braided leads attached, is shown to the right and above the Salt Lake substation. By connecting either two or three of these leads to any desired point, and closing the switch, a single or three phase short circuit could be thrown on the system at that point.

Digitized by Google



[GRAY]

FIG. 5—SIDE VIEW OF ARTIFICIAL LINE

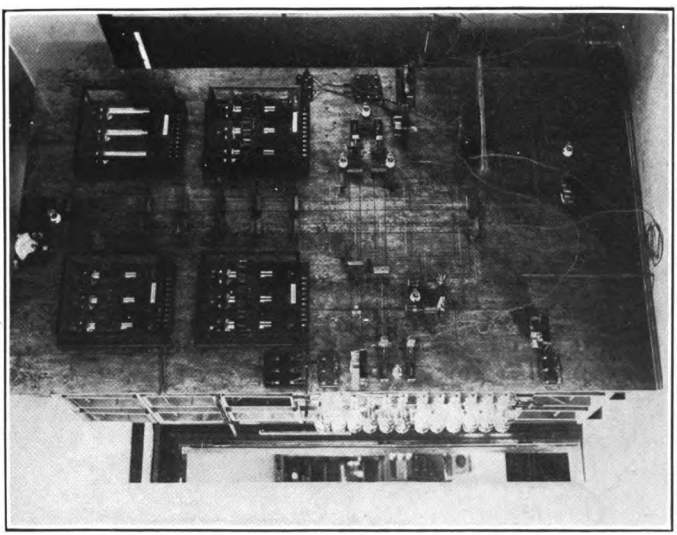
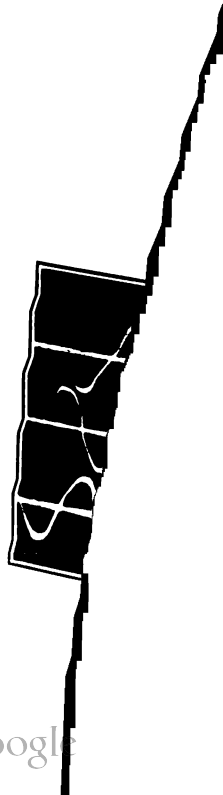


FIG. 4—FRONT VIEW OF ARTIFICIAL LINE

Digitized by Google



Digitized by Google

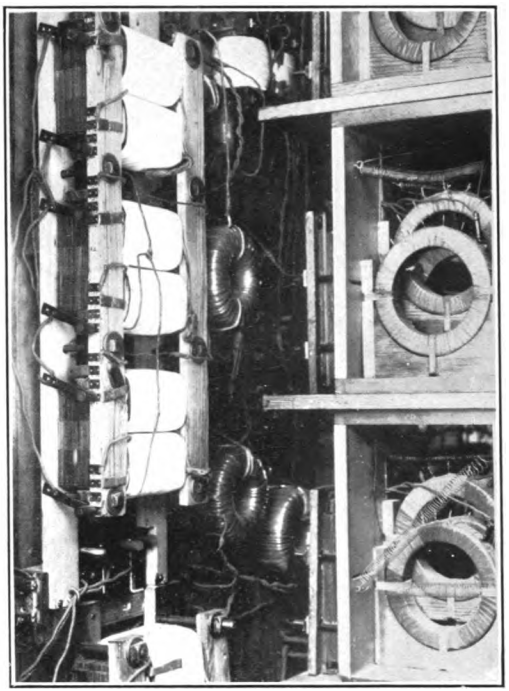


FIG. 6—TRANSFORMERS AND LINE UNITS

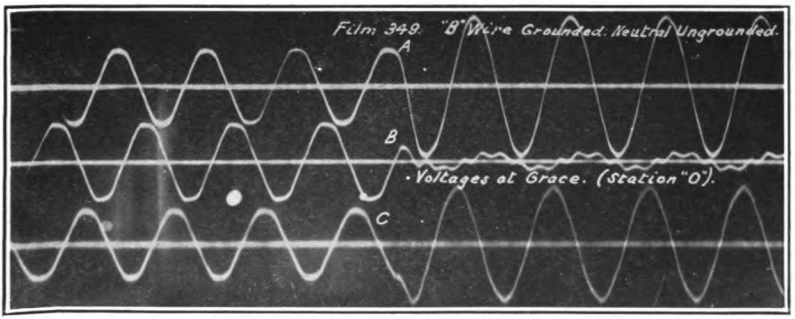


FIG. 8A [GRAY]

Digitized by Google

Digitized by Google

A ground could be studied by means of the grounding device shown below the short-circuiting switch. This consisted of three carbon arcs, the front carbons of each being connected to ground (the condenser neutrals), and the back, by means of lamp cord and a plug, to any wire at the point where it was desired to have a ground. Either a solid or an arcing ground could thus be represented, and the character of the arc could be varied by changing its length or by using different electrode materials.

The switches at Bingham, Garfield, and Salt Lake were made automatic and were worked from the relays, previously referred to, by means of a trigger and spring.

TESTS ON ARTIFICIAL LINE

Description of Tests

On a power-transmission system where each line is a unit in itself, simple overload relays are, in general, satisfactory for tripping off grounded or short-circuited lines. If the lines are interconnected, however, as in a network, some other device must be employed in order that only the section upon which the trouble is located may be disconnected. For this purpose some form of differentially selective relay is generally used. All such relays depend, for their action, upon conditions in the power lines, which show the direction, and in some cases the approximate location, of the disturbance.

Probably the most common form of differentially selective relay is the wattmeter relay. This is provided with two current and two potential coils, and is connected to the circuit according to the well known "two-wattmeter method" for measuring power. Two wattmeters, it can be shown, will correctly measure the total amount of power flowing in a three-wire circuit and will also indicate the direction in which that power is flowing. Hence, if a "two-wattmeter relay" is properly connected to a circuit its moving element should swing in one direction or the other according to the direction in which power is flowing in that circuit.

It is generally assumed that, with a short circuit in a given section of a network, power is flowing toward the short circuit from both ends of that section. Therefore two-wattmeter relays located at the ends of the section should indicate toward the short circuit, and if combined with suitable overload devices should disconnect that section of line.

Digitized by Google

A little consideration will show, however, that it might be possible for the short-circuit power passing a given point toward a single-phase short circuit to be less than the load power flowing in the other direction, over the other two phases. Under these conditions a two-wattmeter relay placed at that point would indicate *away* from the short circuit and, if it operated at all, would operate the wrong switch.

This is something which has frequently happened in practise,

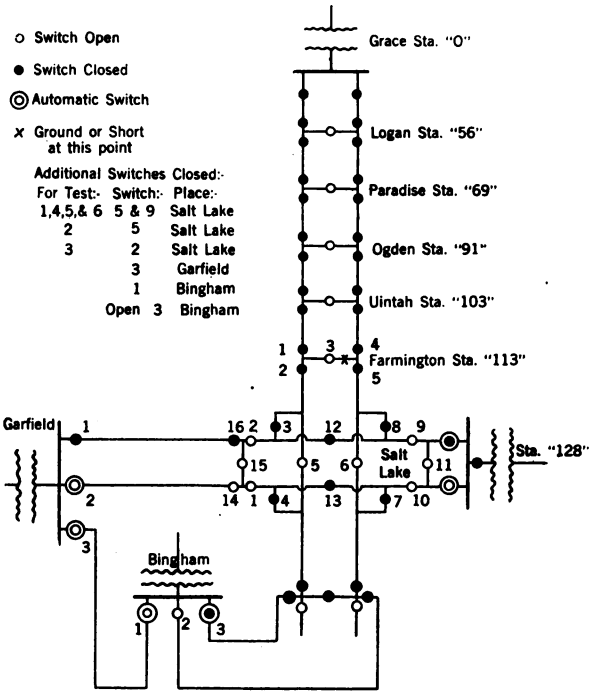


FIG. 7—CONNECTIONS FOR SHORT-CIRCUIT AND GROUND TESTS

and it was also verified by preliminary tests upon the artificial line. It seemed desirable, therefore, to determine the actual phase relations and magnitudes of the currents and voltages at several points along a line, under different conditions of short circuits and grounds, in the hope that such tests would bring out a method of connecting relays so that they would in all cases indicate toward the disturbance.

For such tests the artificial line, combined with an oscillograph, was admirably suited, as simultaneous observations could

Digitized by Google

readily be made at any stations desired. To simplify matters, only a part of the artificial line was used, connected as shown in Fig. 7. For all of the tests power was supplied through the Grace transformers and the two lines between Grace and Salt Lake were used, paralled at both ends. The load was in all cases assumed to be at Salt Lake. When the Bingham and Garfield transformers were used, the line losses between Salt Lake and these stations were treated as part of the load. The load consisted of incandescent lamps combined with the shop motors, running idle, to give a lagging power factor. Attempts to use the motors alone did not work well for it was found impossible to load them with brakes and keep the load steady. In some of the tests, two banks of transformers were used: one carrying load and the other unloaded. The ground or short circuit (indicated by the cross on Fig. 7) was put on the East line at Farmington, in such a position that the currents could be obtained, at Farmington, on both sides of the trouble.

In what follows "ground" always refers to the midpoints of the condensers (all of which were connected together), and "neutral" to the midpoint of the star-connected transformers. The stations where the measurements were taken will hereafter be designated by giving their distance, in miles, from the generator end of the line, instead of by the actual name of the station. Thus Grace, the generating station, is called Station O, Farmington, which is 113 miles from Grace, is called Station 113, etc. This gives more meaning to the relative magnitudes of the current and voltage vectors at different points.

The phase relations between the currents and the voltages at a station were determined at a number of points for six different conditions of the line, namely: normal condition, three-wire short circuit, two-wire short circuit, ground on one wire with neutral of transformers ungrounded, ground on one wire with neutral grounded, and grounds on two wires with neutral grounded. Using the current and voltage plugs, previously described, oscillograms of the three currents and the three voltages to ground (the midpoint of the condensers) were obtained at each station desired. Measurements on these gave the magnitudes and phase relations of the three currents and voltages at that station. The vector representing the voltage between the *A* wire and ground at Station O was then taken as the reference vector. By taking additional oscillograms showing this voltage and one of the currents and voltages at another station, the lag

Digitized by Google

of any current or voltage behind the reference voltage was obtained. The measurements were made in most cases on the second cycle after the short circuit or ground occurred. When only one or two voltage waves were being photographed, the other vibrator circuits were replaced by equal resistances.

Discussion of Oscillograms

Several typical oscillograms, taken during these tests, are shown and discussed.

On most of these oscillograms the waves are shown for a few cycles of normal operation. Then the short circuit or ground occurs and the waves may be seen changing to their final magnitudes and phases. At the instant the change takes place, the waves are very irregular. This is largely because of an uncertain contact in the short-circuiting or grounding switch at the moment of closing. As the transient effects were not being studied, no attempt was made to correct this.

In all of these oscillograms time is increasing from left to right. Unless otherwise noted, the top wave shows the current, or voltage, for the *A* phase, the center wave for the *B* phase, and the bottom wave for the *C* phase. It will be noted that the order in which the waves attain their peak values is top—center—bottom, making the phase rotation, *A-B-C*. In most cases the zero lines are also shown.

The lettering on each oscillogram shows the conditions under which it was taken so that it is necessary here merely to point out some of the interesting features.

The first five oscillograms, Figs. 8A, 8B, 8C, 8D and 8E, show conditions which exist when the *B* wire is grounded, with the neutral of the transformers ungrounded.

In Fig. 8A the voltages of the ungrounded wires are seen to rise almost to delta voltage, while the *B* voltage decreases very decidedly. This voltage does not fall to zero because of the drop in the wire between the point where the oscillogram was taken, and the point where the wire was grounded. (The voltages shown, it will be remembered, are those between each wire and the mid-points of the condensers; or those which would be obtained on an actual system between wires and ground). Fig. 8B shows a slight increase in the magnitude of the current in the grounded wire, and a change in wave shape for all three currents. There is a very peculiar distortion in the waves the instant the ground occurs, and also a slight shift in phase. Fig.

Digitized by Google

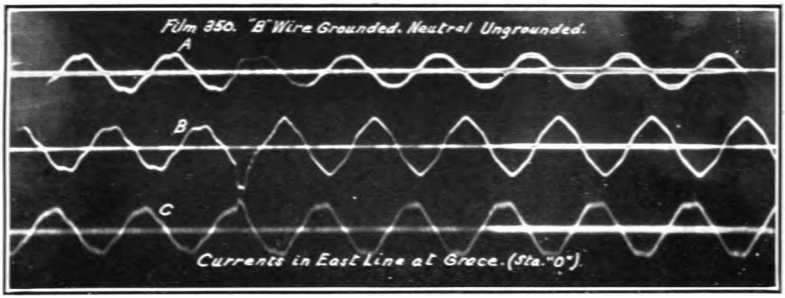


FIG 8B

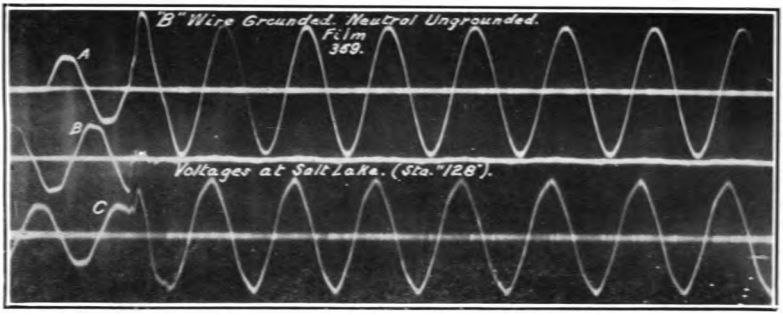


FIG 8C

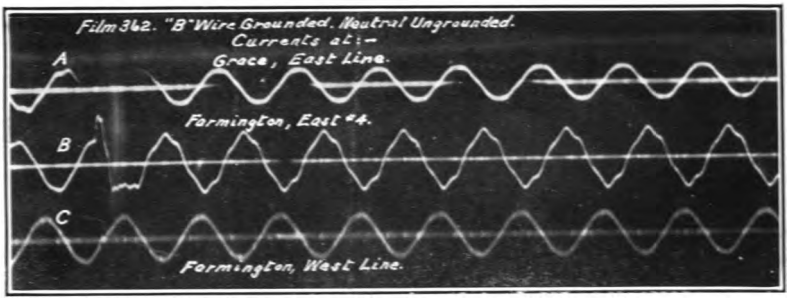


FIG. 8D

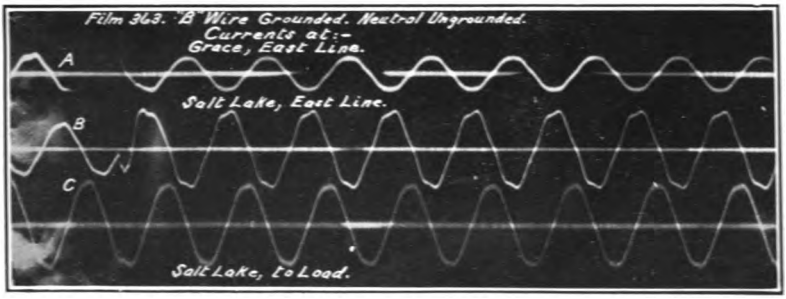


FIG. 8E

Digitized by Google

Digitized by Google

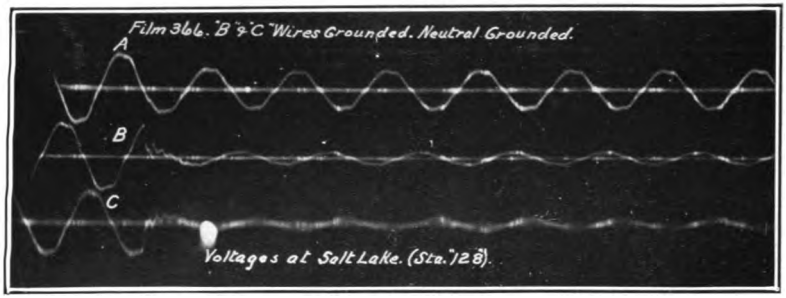


FIG 9A

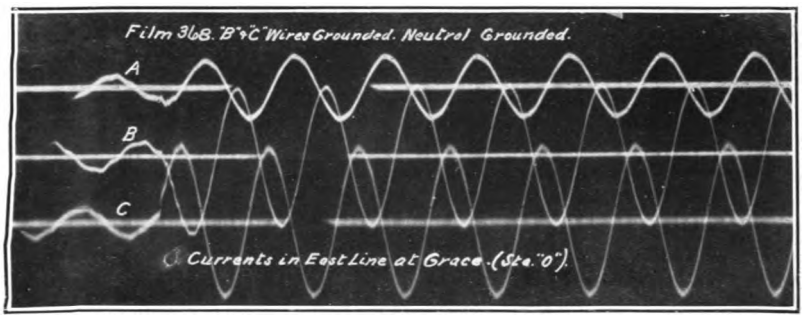


FIG. 9B

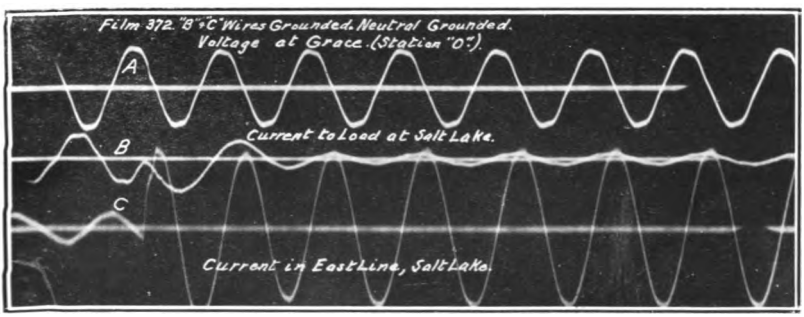

Film 372. "B" & "C" Wires Grounded. Neutral Grounded.
Voltage at Grace. (Station "0").
A
Current to Load at Salt Lake.
B
C
Current in East Line, Salt Lake.

FIG. 9C

[GRAY]

Digitized by Google

Digitized by Google

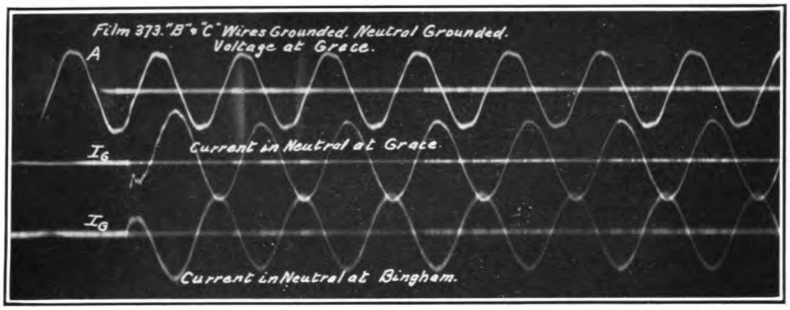


FIG. 9D

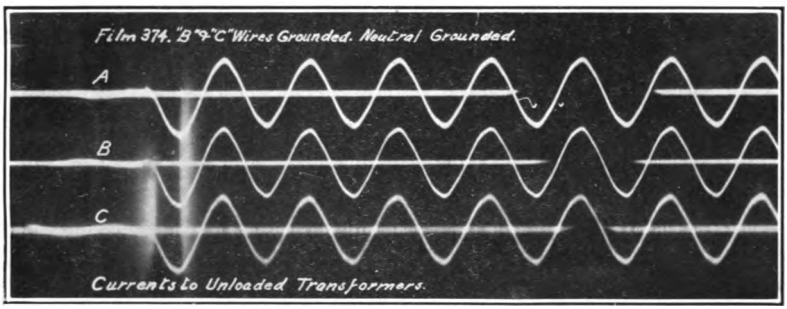


FIG 9E

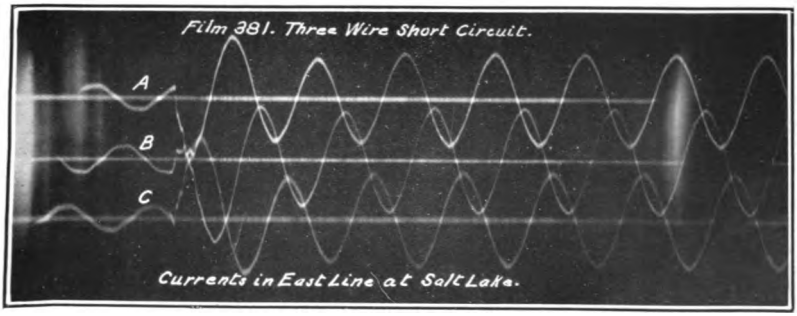


FIG. 10A

Digitized by Google

Digitized by Google

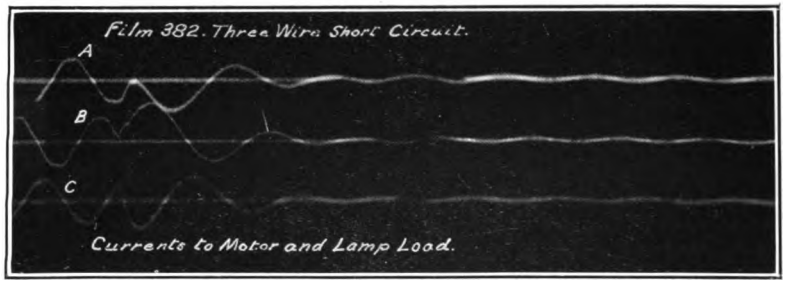


FIG. 10B

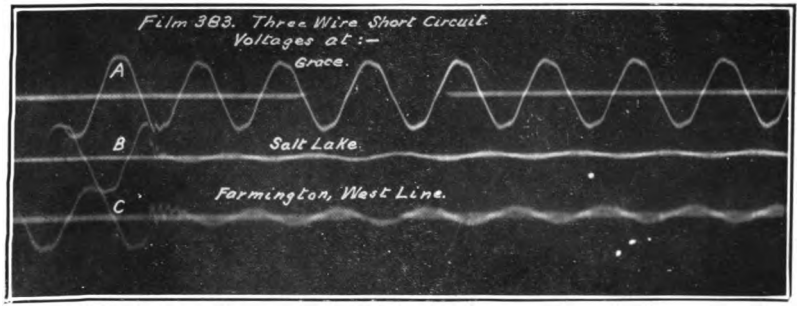


FIG. 10C

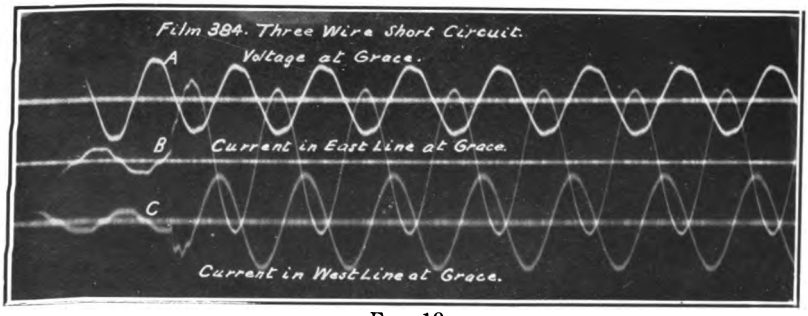


FIG. 10D

Digitized by Google

Digitized by Google

8c shows much the same effects as were brought out in Fig. 8A. They are more pronounced, however, because this oscillogram was taken much nearer to the grounded point of the line. The comments given for Fig. 8B apply also to Figs. 8D and 8E.

Figs. 9A, 9B, 9C, 9D and 9E illustrate the grounding of the *B* and *C* wires when the neutral of the transformers is grounded. Fig. 9A shows the three voltages at a point near where the wires were grounded and Fig. 9 B shows the currents flowing out from the generating station over the East line, upon which the ground was placed. Both of these oscillograms show the effects which would be expected, and require no discussion. The middle wave on Fig. 9c shows the *B* current at Station 128, flowing to the motor load. At the instant the ground is thrown on this is seen to shift in phase by about 180 degrees, due to the fact that the motor pumps power back into the line. The current then slowly decreases in magnitude and changes in phase as the motor slows down. The lower wave, (showing the current at the load end of the East line) also reverses, but this is because the current in that wire now flows toward the grounded point instead of toward the load. The two lower waves on Fig. 9D show the currents flowing in the neutrals at the generator and load. There is, of course, no current until the wires are grounded.

Fig. 9E is a very interesting one. This shows the currents flowing to a bank of unloaded transformers, connected star-delta. Before the wires are grounded the three currents are very small and differ in phase by 120 degrees. With the grounds on the system these currents all increase to about the same magnitude and are all in phase with each other. The probable explanation of this is given later under the discussion of Fig. 16.

Figs. 10A, 10B, 10c and 10D show the current and voltage waves for a few cycles before and after a three-phase short circuit is thrown on the system. Fig. 10A shows the currents in the load end of the East line. When the short circuit occurs the direction of power flow is reversed: becoming toward the short circuit. Hence, the direction of current flow reverses and the currents are seen to change in phase by approximately 180 degrees. Fig. 10B shows the currents taken by the motor load. These reverse because of the pumping-back action of the motor, and then decrease toward zero as the motor slows down. Fig. 10c shows the voltage waves at three different points on the system. The magnitudes of the waves are roughly propor-

Digitized by Google

tional to the distances from the short circuit. The center and bottom waves of Fig. 10D show the current at the generator end of the East and West lines, respectively.

Description of Figures

Figs. 11, 12, 13, 15, 16 and 17 were drawn from measurements made on these oscillograms and on others not shown here. These figures show the magnitudes and phase relations of the currents and voltages at both ends of the line and at several intermediate points.

In explanation of the figures, it may be said that the vectors are assumed to be rotating *counter* clockwise, or that the phase rotation is *A-B-C*. The lines from *G* to the vertices of the triangles represent, in magnitude and phase, the peak voltages between each wire and ground; the sides of the triangles consequently represent the line voltages. The peak currents in the *A*, *B* and *C* wires are represented by the vectors marked I_A, I_B, and I_C respectively. At Station 113 (East Line) two diagrams are shown; one for the conditions on each side of the short circuit or ground. The diagrams marked "Generator" were obtained by adding vectorially the currents for the two lines, as no oscillograms were taken at this point. In Figs. 15, 16 and 17 dotted lines are drawn from the vertices of the triangles to a point marked *O*. These lines are the medians of the triangles, and represent the voltages which would be impressed on three equal impedances connected in star between the wires, with the neutral free: such, for instance, as the potential coils of three star-connected wattmeters or relays.

For Figs. 11, 12 and 13 (normal condition, three-wire and two-wire short circuits) these medians coincide with the vectors representing the voltages to ground, since the latter are voltages impressed on three equal impedances connected in star.

In all of the tests the voltages to ground were obtained from the oscillograms, and the voltages represented by the medians were used in computing the wattmeter readings, now to be discussed.

The four straight lines shown at each station between the diagrams for the East and West lines represent (to scale) the readings which would be given by three star-connected wattmeters at that point, and the sum of the three readings. These were obtained by multiplying each star (median) voltage by the "in phase" component of its corresponding

Digitized by Google

current. These computations are shown in Tables IV-IX, inclusive. Numerous small discrepancies appear in these data; such, for instance, as the generator wattage not being equal to

CALCULATION OF WATTMETER READINGS FOR EACH STATION

The column headed "Total Watts" shows the magnitude and direction of the flow of power at each station. (Power which flows from the generator to the load is assumed to be positive. Power flowing toward the generator is assumed to be negative.)

The column headed "Watts per Phase" shows the readings which would be given by three star-connected wattmeters having the neutral of the potential coils free.

TABLE IV.

Test No. 1. Normal condition.

Station	Line or switch	Wire	Peak Voltage	Peak current		Watts per phase.	Total watts.
				Actual	"In phase" Component		
Generator		A	931	2.05	2.00	931	
		B	894	2.10	2.07	925	2840
		C	875	2.30	2.24	980	
0	West	A	931	1.00	0.97	450	
		B	894	1.05	1.03	460	1380
		C	875	1.10	1.07	469	
0	East	A	931	1.05	1.03	480	
		B	894	1.15	1.15	515	1500
		C	875	1.25	1.15	503	
113	West	A	...	1.05			
		B	...	1.10			
		C	...	1.20			
113	East	A	780	1.10	0.97	378	
		B	780	1.30	0.93	362	1080
		C	740	1.20	0.97	359	
128	West	A	798	1.05	1.03	411	
		B	780	1.10	1.03	401	1170
		C	740	1.20	0.97	359	
128	East	A	798	1.10	0.95	379	
		B	780	1.30	0.95	370	1130
		C	740	1.25	1.03	381	
128	Loaded transformers	A	798	1.85	1.79	715	
		B	780	2.05	1.90	741	2120
		C	740	2.00	1.79	661	
128	Unloaded transformers	A	798	0.30	0.14	56	
		B	780	0.25	0.14	55	163
		C	740	0.30	0.14	52	

the sum of the wattages of the two lines. These discrepancies are easily explained, however, when it is recalled that the calibration of an oscillograph is, at best, somewhat doubtful; that the maximum deflection on the oscillograms rarely exceeded

Digitized by Google

one half of an inch; and that after the currents had been scaled and plotted, their "in phase" components (often very small) had to be scaled again from the drawing. Hence a high degree of accuracy should not be expected.

TABLE V.

TEST NO. 2. THREE-WIRE SHORT CIRCUIT.

Station	Line or switch	Wire	Peak Voltage	Peak current		Watts per phase	Total watts
				Actual	"In phase" Component		
Generator		A	780	9.55	5.66	2210	
		B	770	10.95	6.14	2360	6450
		C	703	10.15	5.35	1880	
0	West	A	780	4.15	2.55	995	
		B	770	4.50	2.86	1100	2920
		C	703	4.20	2.34	825	
0	East	A	780	5.50	3.04	1180	
		B	770	6.40	3.31	1270	3530
		C	703	5.80	3.07	1080	
113	West	A	171	4.20	2.83	242	
		B	171	4.40	3.14	268	730
		C	171	4.25	2.59	221	
113	East	A	...	....	....	...	
		B	...	....	....	...	...
		C	...	....	....	...	
128	West	A	95	4.15	3.07	146	
		B	95	4.40	3.51	167	450
		C	95	4.25	2.97	141	
128	East	A	95	3.95	−2.69	−128	
		B	95	4.50	−3.04	−144	−410
		C	95	4.00	−2.86	−136	
128	Loaded Transformers	A	95	0.30	0.28	13	
		B	95	0.30	0.28	13	40
		C	95	0.30	0.28	13	

Discussion of Figures

Fig. 11. *Normal Condition.* This figure shows the relations existing in the line under normal operating conditions. The phases are slightly unbalanced here because of an unbalanced load which was connected to the laboratory mains. An interesting point to be noted in these diagrams is the increase in the

Digitized by Google

TABLE VI

TEST NO. 3. TWO-WIRE SHORT CIRCUIT

Station	Line or switch	Wire	Peak voltage	Peak current		Watts per phase	Total watts
				Actual	"In phase" Component		
Generator		A	872	3.40	3.04	1326	
		B	698	10.20	8.84	3080	4860
		C	829	8.85	1.10	456	
0	West	A	872	1.64	1.48	646	
		B	698	4.11	3.78	1320	2310
		C	829	3.61	0.82	340	
0	East	A	872	1.64	1.38	600	
		B	698	6.11	5.16	1800	2520
		C	829	5.30	0.28	116	
91	West	A	741	1.60	1.56	578	
		B	457	4.15	4.14	946	1490
		C	490	3.60	−0.14	−34	
91	East	A	730	1.65	1.61	589	
		B	435	5.90	5.61	1221	1540
		C	435	5.25	−1.24	−270	
113	West	A	665	1.60	1.56	519	
		B	360	4.05	4.05	730	1140
		C	392	3.55	−0.55	−108	
113	East No. 4	A	720	1.80	1.47	529	
		B	381	5.95	4.87	929	840
		C	381	5.75	−3.22	−614	
113	East No. 5	A	720	1.80	1.47	529	
		B	381	4.85	−3.31	−630	760
		C	381	5.15	4.50	858	
128	West	A	675	1.60	1.60	544	
		B	349	3.95	3.59	626	1030
		C	349	3.70	−0.83	−145	
128	East	A	675	1.95	1.65	557	
		B	349	5.10	−3.95	−689	530
		C	349	4.95	3.78	660	
128	Loaded Transformers	A	675	3.80	3.31	1118	
		B	349	1.65	0.74	129	1660
		C	349	2.35	2.35	410	

Digitized by Google

current lag in going from the generator to the load. This is, of course, due to the fact that the lagging current of the load is partly neutralized at the generator by the leading charging current.

TABLE VII

TEST NO. 4. ONE WIRE GROUNDED. NEUTRAL UNGROUNDED

The voltages are the dotted lines shown on Fig. 15.

Station	Line or switch	Wire	Peak voltage.	Peak current		Watts per phase	Total watts
				Actual	"In phase" component		
Generator		A	975	1.75	1.72	839	
		B	895	2.80	2.72	1218	3210
		C	904	2.55	2.55	1150	
0	West	A	975	0.90	0.90	448	
		B	895	1.30	1.17	524	1500
		C	904	1.30	1.17	529	
0	East	A	975	0.85	0.83	405	
		B	895	1.55	1.48	661	1660
		C	904	1.40	1.31	592	
113	West	A		1.05			
		B		1.35			
		C		1.10			
113	East No. 4	A	865	1.15	1.03	446	
		B	789	1.55	1.45	571	1490
		C	780	1.40	1.21	472	
113	East No. 5	A	865	1.00	1.00	432	
		B	789	1.45	0.93	366	1200
		C	780	1.05	1.03	402	
128	West	A	865	1.00	1.00	432	
		B	808	1.20	1.14	460	1280
		C	751	1.15	1.03	387	
128	East	A	865	1.00	.0.96	415	
		B	808	1.55	0.90	363	1170
		C	751	1.10	1.03	387	
128	Loaded transformers	A	865	2.10	2.07	895	
		B	808	2.10	2.05	829	2500
		C	751	2.25	2.07	777	

The data for these diagrams were obtained from measurements made on the oscillograms for Tests 4 and 6, using the two or three cycles shown previous to the occurrence of the ground.

Fig. 12. *Three-Wire Short Circuit.* This figure is not of much importance, for a three-wire short circuit very seldom

Digitized by Google

TABLE VIII

TEST NO. 5. ONE WIRE GROUNDED. NEUTRAL GROUNDED.

The voltages are the dotted lines shown on Fig. 16.

Station	Line or switch	Wire	Peak voltage	Peak current		Watts per phase	Total watts
				Actual	"In phase" component		
Generator		A	813	4.25	4.25	1730	
		B	721	8.80	6.18	2230	4790
		C	870	3.80	1.90	826	
0	West	A	813	2.00	1.93	785	
		B	721	3.40	2.69	970	2210
		C	870	1.75	1.04	452	
0	East	A	813	2.35	2.21	940	
		B	721	5.45	3.38	1220	2510
		C	870	2.05	0.80	348	
91	West	A	650	1.95	1.52	495	
		B	314	3.45	2.97	466	1330
		C	694	1.70	1.07	371	
91	East	A	655	2.25	2.18	715	
		B	290	5.40	4.25	616	1660
		C	675	2.00	0.97	327	
113	West	A	608	1.95	1.59	483	
		B	285	3.40	2.76	393	1170
		C	650	1.70	0.90	292	
113	East No. 4	A	550	2.20	2.07	570	
		B	123	5.40	3.80	234	980
		C	580	2.45	0.59	171	
113	East No. 5	A	550	2.25	2.21	609	
		B	123	7.60	−5.00	−308	430
		C	580	2.25	0.45	130	
128	West	A	575	1.85	1.38	396	
		B	204	3.40	3.00	306	1010
		C	608	1.85	1.00	304	
128	East	A	575	2.30	2.21	635	
		B	204	7.75	−5.49	−560	310
		C	608	2.50	0.76	231	
128	Loaded transformers	A	575	2.85	2.76	793	
		B	204	1.70	−0.66	−67	1520
		C	608	2.85	2.62	795	
128	Unloaded transformers	A	575	2.60	1.35	388	
		B	204	2.60	−2.28	−232	20
		C	608	3.00	−0.45	−137	

Digitized by Google

occurs in practise. When it does occur, relays generally work properly, since the currents and the voltages are balanced. The voltages are seen to decrease from the generator to the short

TABLE IX

TEST NO. 6. TWO WIRES GROUNDED. NEUTRAL GROUNDED

The voltages are the dotted lines shown on Fig. 17.

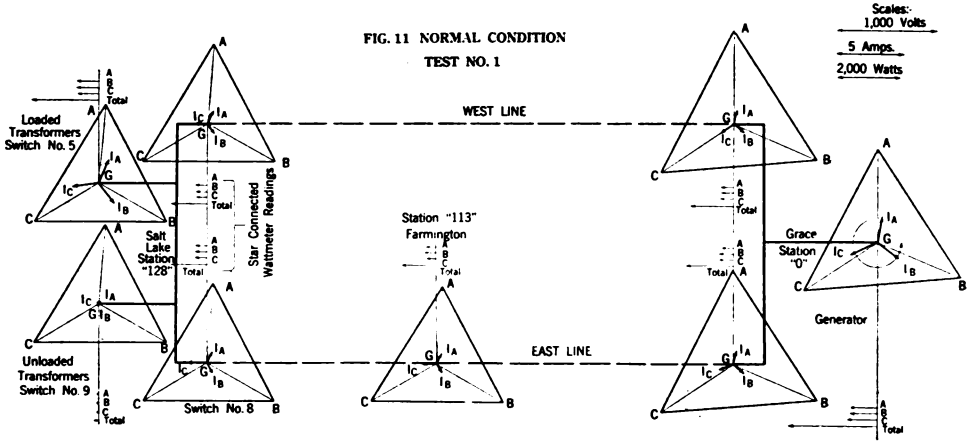
Station	Line or switch	Wire	Peak voltage	Peak current		Watts per phase	Total watts
				Actual	"In phase" component		
Generator		A	860	5.35	3.80	1633	
		B	707	10.00	6.50	2290	5630
		C	803	10.60	4.25	1708	
0	West	A	860	2.55	1.86	800	
		B	707	4.05	2.76	975	2520
		C	803	4.20	1.86	748	
0	East	A	860	2.75	1.86	800	
		B	707	6.00	3.80	1341	3190
		C	803	6.40	2.62	1051	
113	East No. 4	A	352	3.05	2.28	401	
		B	176	6.10	5.60	492	740
		C	176	6.30	−1.69	−149	
113	East No. 5	A	352	2.65	2.07	364	
		B	176	5.80	−5.80	−510	−190
		C	176	6.70	−0.55	−48	
128	West	A	370	2.80	2.28	421	
		B	176	4.00	4.00	352	800
		C	199	4.20	0.28	28	
128	East	A	370	2.70	1.93	357	
		B	176	5.85	−4.90	−431	−290
		C	199	6.70	−2.17	−216	
128	Loaded transformers	A	370	2.75	2.21	409	
		B	176	0.40	0.10	9	450
		C	199	1.10	0.28	28	
128	Unloaded transformers	A	370	2.80	1.79	331	
		B	176	2.80	−0.83	−73	0
		C	199	2.80	−2.59	−258	

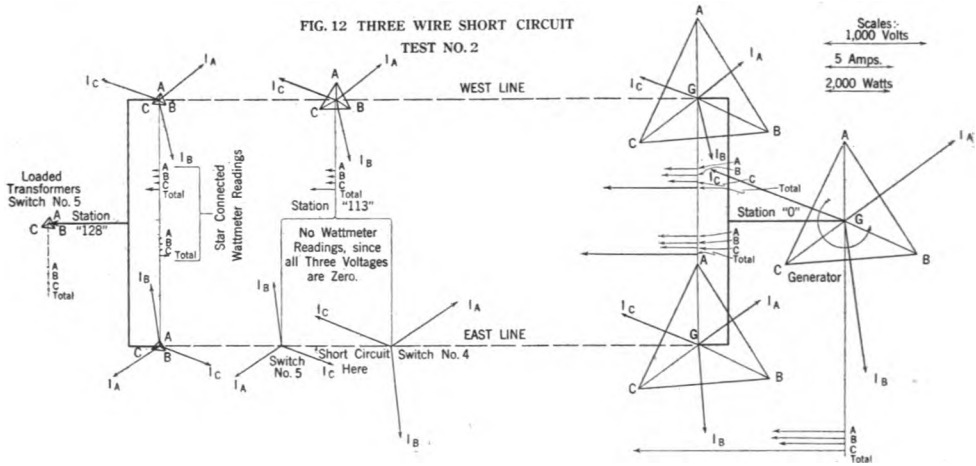
circuit. The power put into the line during a short circuit is not the tremendous amount sometimes supposed. In this case it is only a little more than twice that supplied under normal operation, in spite of the fact that the generator voltage is

Digitized by Google

maintained almost at normal value. The current, however, is over four times as large as the normal current.

Fig. 13. *Two-Wire Short Circuit.* These oscillograms were taken before the short-circuiting switch was arranged to catch the actual short circuit on the oscillogram. Hence the measure-





ments were made on about the tenth or twelfth cycle after the short circuit occurred. The currents and voltages are, naturally, very much unbalanced. All three currents are larger than normal, the current in the good or A wire increasing because of the fact that the motor load takes more current when the voltage

Digitized by Google

triangle is unbalanced. The power delivered to the load is about 75 per cent of the normal amount. The power given out by the generator is about 70 per cent greater than normal, and about 25 per cent less than that for the three-wire short circuit.

The most interesting thing in this figure is the wattmeter readings. The *A* wattmeter is seen to indicate toward the load in every case. The *B* wattmeter indicates *toward* the short circuit at all points. The *C* wattmeter indicates *away* from the short circuit, except at stations some distance away. The *B* wattmeter is, thus, the only one which can be depended upon to show the direction of the short circuit. The arrow showing the total power, it will be noticed, points toward the load at every station. This means that relays connected according to the two-wattmeter principle can not work properly except on a system where the load is small compared with the power expenditure during short circuit.

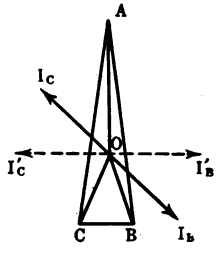


FIG. 14

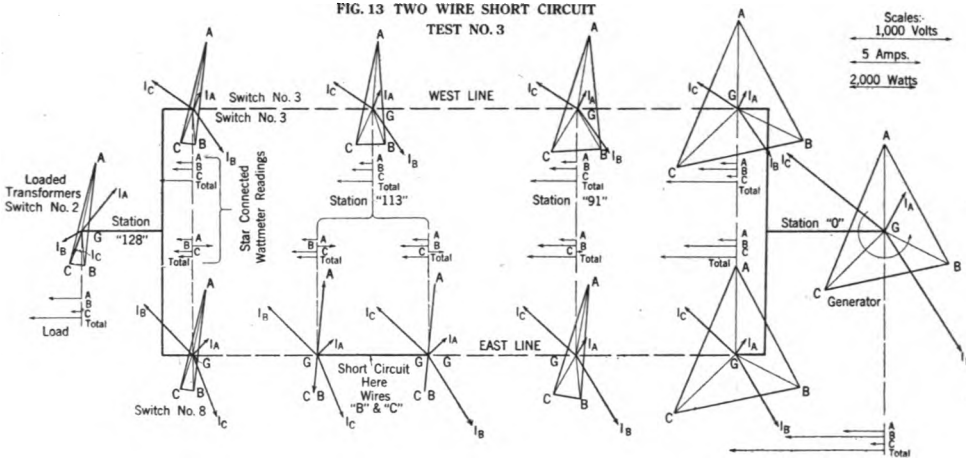
The explanation of the backward reading of the *C* meter may be given briefly with the aid of Fig. 14. The triangle represents the delta voltages at some point near the short circuit, and I_B and I_C represent the currents in wires *B* and *C*. The phase rotation is assumed to be *A*-*B*-*C*, and the short circuit is between wires *B* and *C*.

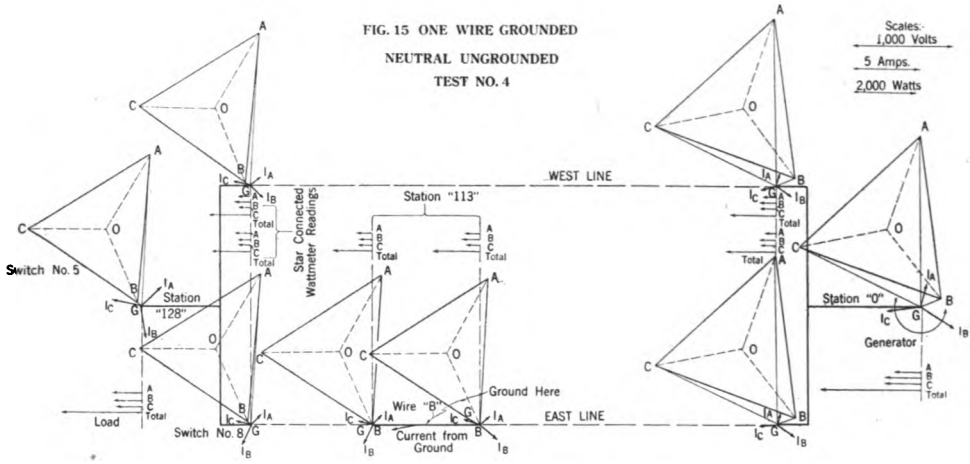
With a non-inductive line and with no load current flowing, the short-circuit current would be in phase with *B*-*C*, or would take the position I_B'-I_C'. Since, however, the inductive reactance of a line generally exceeds the resistance, the current vector will lag by a considerable angle, and will take some such position as I_B-I_C. This makes the voltage E_{CO} and the current I_C more than 90 degrees out of phase, and causes the *C* wattmeter to read backwards. It may readily be seen that if the phase rotation is reversed the *B* meter will be the one which reads backwards.

Fig. 15. *One Wire Grounded. Neutral of Transformers Ungrounded.* For this test the *B* wire at Station 113 on the East line was connected to ground through the grounding device shown in Fig. 4. (Ground, as stated at the beginning of this chapter under *Description of Tests* means the midpoints of the condensers, all of which were connected together. Neutral refers to the midpoints of the star-connected transformers.)

Digitized by Google

In these diagrams the voltage triangle is only slightly distorted, but is greatly displaced with respect to ground potential. This point (ground potential) comes completely outside of the triangle. The ratio of delivered power to generator power is greater than



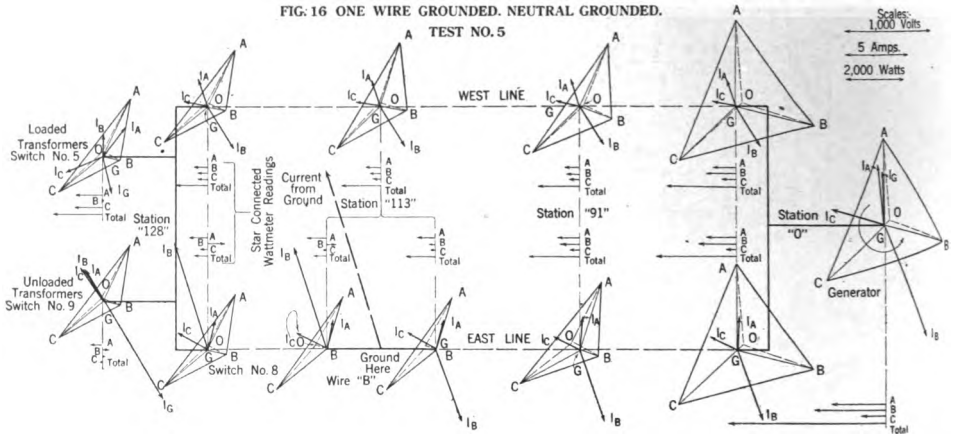


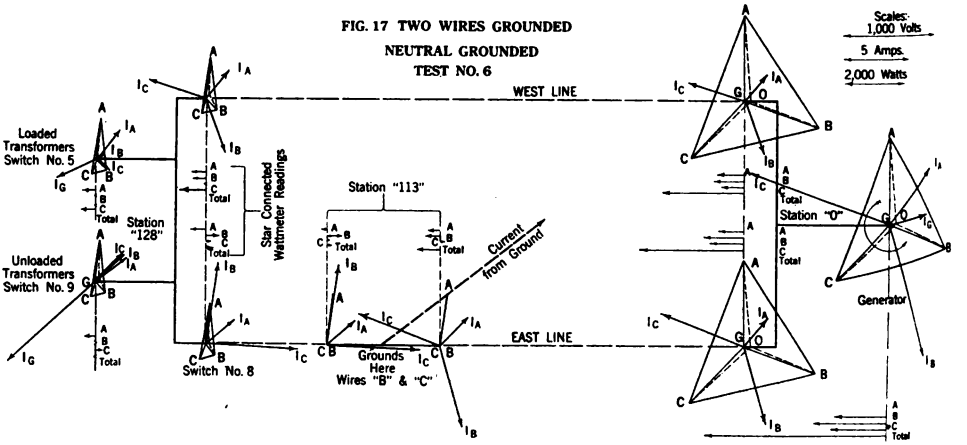
under normal conditions, probably because the higher potential above ground produces a greater charging current. This results in a higher power factor in the line, and hence a lower line loss. The wattmeter readings in this case are nearly the same as under normal conditions. Therefore, wattmeter relays can not be

Digitized by Google

used to show the direction of such a ground. A dead ground of this kind, however, is not serious, except on very high-voltage systems.

Fig. 16. *One Wire Grounded. Neutral of Transformers Grounded.* The neutrals of all three banks of transformers were





connected to ground, and a ground thrown on the system at the usual place (the East line at station 113). The voltage triangle, of course, becomes very much unbalanced. The wattmeter readings are again seen to behave in a rather unexpected manner, the *B* wattmeter being the only one which correctly shows, at

Digitized by Google

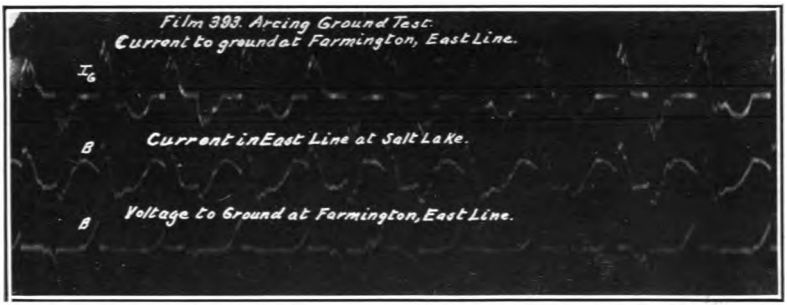

Film 393. Arcing Ground Test.
Current to ground at Farmington, East Line.
I_0
B
Current in East Line at Salt Lake.
B
Voltage to Ground at Farmington, East Line.

FIG. 18A

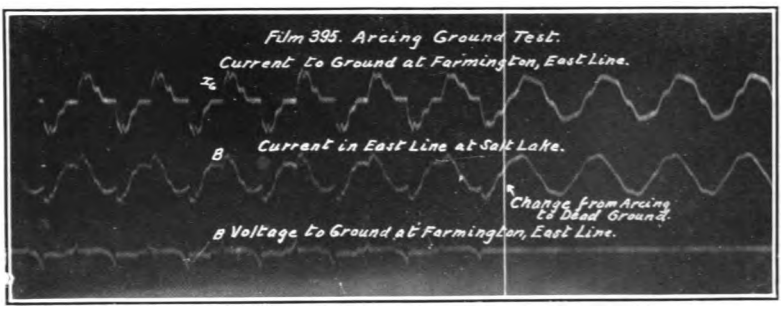

Film 395. Arcing Ground Test.
Current to Ground at Farmington, East Line.
I_0
B
Current in East Line at Salt Lake.
Change from Arcing to Dead Ground.
B Voltage to Ground at Farmington, East Line.

FIG. 18B

Digitized by Google

Digitized by Google

all stations, the direction of the ground. The vectors marked I_c show the currents flowing into the system through the grounded neutrals. The difference in the magnitudes of this current for the loaded and unloaded transformers is due to the large line impedance between the loaded transformers and the Salt Lake busbars.

The currents in the three wires to the "Unloaded Transformers" are nearly equal and in phase. This results from the star-delta connection, and may be explained as follows: The voltages from wires *A* and *C* to ground are somewhere near normal, and this tends to keep up the voltage of the *B* transformer on the low-tension (delta) side. This induces a voltage in the high side of this transformer and sends a current out over the grounded wire. As the only current which can flow in the low-tension side must circulate around the delta, the three line currents must be approximately equal and in phase. For this reason the currents in all three wires will be abnormal when one wire is grounded; and the nearer the ground is to a bank of load transformers, the greater will be the current in that bank. Hence, a bank of small star-delta load transformers is liable to serious injury if its neutral is grounded.

The single vector at Farmington (station 113) between the two diagrams represents the current flowing into the system at the point where the wire is grounded. It is equal to the sum of the currents (flowing in opposite directions) in the *B* wire at that point.

Fig. 17. *Two Wires Grounded. Neutral of Transformers Grounded.* This case resembles the preceding one, except that it is more severe. The *B* and *C* wires were grounded at station 113. The voltages and power at the load are much less than in Fig. 16, and some of the meters have reversed. The *B* meter is again the only one which can be depended upon to read correctly. As practically all of the discussion given for the preceding case applies to this case, it will not be repeated here.

Discussion of Arcing Ground Tests

The following test has no connection with the preceding, but is presented as a matter of interest. This test was made with the regular connections shown in Fig. 7 for Tests 1, 4, 5, and 6. Wire *B* of the East line was grounded at station 113 using the grounding device shown in Fig. 4. Fig. 18A shows only the steady condition (if it can be called such) of the arcing

Digitized by Google

ground. The top wave shows the ground current at station 113, the center one the current in the B wire at station 128 (East Line) and the bottom one the voltage from the B wire to ground at station 113. The arc is seen to break at the end of each half cycle of the voltage wave, and the current remains at zero until the voltage has risen considerably. It then increases rapidly to almost its final value. The current in the center wire is, of course, a combination of the arc current and the load current. Hence it has a value while the arc is broken.

Fig. 18B shows the waves while an arcing ground is being displaced by a dead ground. The most surprising feature here is that the arcing ground takes more current than the dead ground. This is because of the fact that, during each alternation, the electrostatic capacity of the system must be charged to a certain value. As quantity is equal to the product of current and time, it follows that if the beginning of the charge is delayed, the current must increase to a higher value in order to get the required charge into the system in the given time. Planimeter measurements on Fig. 18B show that the area under the irregular curve due to the arcing ground, is approximately equal to the area under the curve due to the dead ground. Hence, the quantities, which are proportional to the areas, are about equal in the two cases, and the average values of the currents are equal. The peaks and effective values, however, are not.

These observations were made using carbon electrodes. The effect of metallic electrodes is to make this phenomenon more pronounced. It should be remembered, however, that an arc on a 1000-volt system may have entirely different characteristics from one on a 44,000-volt system.

APPENDIX A

Derivation of Formula Used in Calculating the Capacities

Given wire 1 of radius r, length $2L$, $\frac{d}{2}$ units above the ground, and having a quantity of electricity q per unit length. To find its potential above ground.

As the potential of one point with respect to another is defined as the work which must be done in carrying a unit positive charge from the second point to the first, it is necessary first to find the force acting, perpendicular to the wire, on a unit charge at any distance from the wire.

Digitized by Google

This force, at any point P is equal to:

$$2\int_0^L \frac{q\,dl}{l^2 \pm x^2} - \frac{x}{\sqrt{l^2+x^2}} = 2\,q\,x^{-1}\,\frac{l}{\sqrt{l^2+x^2}}\Bigg|_0^L = \frac{2qL}{x\sqrt{L^2+x^2}}$$

If x is small in comparison with L, this may be written:

$$\text{Force} = \frac{2q}{x}$$

Using the method of images in Fig. 19 let 4 be the image of 1 with respect to ground. The potential, $V_{1,4}$, between 1 and 4 is then equal to twice the potential, V_1, between 1 and ground. From the definition given above, $V_{1,4}$ is seen to be equal to the

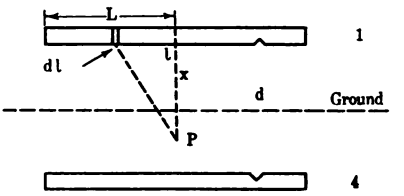


FIG 19

integral of the force acting on a unit positive charge over the distance between the two wires, or:

$$V_{1,4} = \int_{d-r}^{r} \frac{2\,q\,(-dx)}{x} - \int_{d-r}^{r} \frac{2\,(-q)(-dx)}{d-x}$$

the first term being for wire 1 and the second for wire 4. Integrating:

$$V_{1,4} = 2\,q\left[-\log_\epsilon x + \log_\epsilon (d-x)\right]_{d-r}^{r}$$

$$= 2\,q\log\frac{d-r}{r} + 2\,q\log\frac{d-r}{r}$$

$$= 4\,q\log_\epsilon\frac{d}{r}$$

since r is negligible in comparison with d.

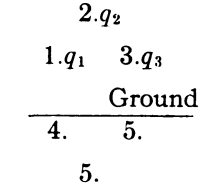
Digitized by Google

Hence, the potential from 1 to ground (which is one-half of that between 1 and 4), is:

$$V_1 = 2\,q \log_\epsilon \frac{d}{r}$$

It may readily be seen that the effect of having other charged conductors in the field, is to add a similar term for each conductor; in which q is the charge per unit length on that conductor. The logarithmic part of each term is the ratio of the initial to the final distance of the unit charge from each conductor, as the unit charge is carried from the image of the conductor whose potential is being found, to the conductor itself. Thus in a three-phase system, the potential of wire 1 above ground is

$$V_1 = 2\,q_1 \log_\epsilon \frac{d_{1,4}}{r_1} + 2\,q_2 \log_\epsilon \frac{d_{2,4}}{d_{1,2}} + 2\,q_3 \log_\epsilon \frac{d_{3,4}}{d_{1,3}}$$



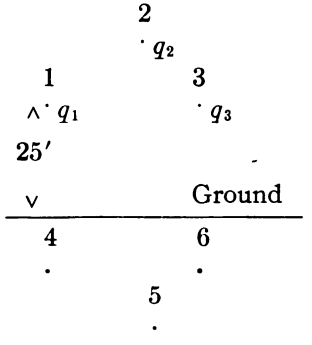
$d_{1,2}$, $d_{1,3}$ etc., represent the distances between wires 1 and 2, 1 and 3, etc.

APPENDIX B.

Calculation of Capacities for West Line, Grace to Logan Derivation of General Formula for Calculating Capacities

The wires are No. 2 copper, 0.2576 in. in diameter, at the corners of an equilateral triangle 9 ft. on a side. The average height of the lower wires above ground is 25 feet.

Using the method of images, let q_1, q_2, q_3 be the charges per unit length on the conductors. Let the voltages from wires to ground be



$$V_1 = A \sin \omega t$$
$$V_2 = A \sin (\omega t - 120°)$$
$$V_3 = A \sin (\omega t - 240°)$$

Digitized by Google

From the proof given in Appendix B,

$$V_1 = 2\,q_1 \log_\epsilon \frac{d_{1,4}}{r_1} + 2\,q_2 \log_\epsilon \frac{d_{2,4}}{d_{1,2}} + 2\,q_3 \log_\epsilon \frac{d_{3,4}}{d_{1,3}} = A \sin \omega t$$

Referring to the sketch above,

$d_{1,4} = 50$ ft. or 600 in. $\quad d_{1,2} = 9$ ft.
$r_1 = 0.1288$ in. $\quad d_{2,4} = 50.8$ ft. $\quad d_{2,3} = 65.6$ ft.
$d_{2,4} = 58.0$ ft. $\quad d_{1,3} = 9$ ft.

Substituting in the formula above:

$$A \text{ sin. } \omega t = 2\,q_1 \log_\epsilon \frac{600}{0.1288} + 2\,q_2 \log_\epsilon \frac{58.0}{9.0} + 2\,q_2 \log_\epsilon \frac{50.8}{9.0}$$

In the same way:

$$A \sin (\omega t - 120°) = 2\,q_1 \log_\epsilon \frac{58.0}{9.0} + 2\,q_2 \log_\epsilon \frac{787.2}{0.1288} + 2\,q_3 \log_\epsilon \frac{58.0}{9.0}$$

and

$$A \sin (\omega t - 240°) = 2\,q_1 \log_\epsilon \frac{50.8}{9.0} + 2\,q_2 \log_\epsilon \frac{58.0}{9.0} + 2\,q_2 \log_\epsilon \frac{600}{0.1288}$$

From these equations:

$$A \sin \omega t = 2 \times 2.303\,(3.668\,q_1 + 0.809\,q_2 + 0.752\,q_3)$$
$$A \sin (\omega t - 120°) = 2 \times 2.303\,(0.809\,q_1 + 3.786\,q_2 + 0.809\,q_3)$$
$$A \sin (\omega t - 240°) = 2 \times 2.303\,(0.752\,q_1 + 0.809\,q_2 + 3.668\,q_3)$$

Now let $B = \dfrac{A}{2 \times 2.303 \times 0.809}$

$$B \sin \omega t = 4.534\,q_1 + q_2 + 0.929\,q_3$$
$$B \sin (\omega t - 120°) = q_1 + 4.680\,q_2 + q_3$$
$$B \sin (\omega t - 240°) = 0.929\,q_1 + q_2 + 4.534\,q_3$$

Digitized by Google

Solving these equations gives

$$q_1 = B\,\frac{1.006 \sin \omega t + 0.0095 \cos \omega t}{3.605}$$

$$q_2 = 0.2742\,B \sin (\omega t - 120°)$$

To find the maximum value of q_1, differentiate with respect to ωt.

$$\frac{d\,q_1}{d\,\omega t} = 1.006 \cos \omega t - 0.0095 \sin \omega t = 0$$

$$\tan \omega t = \frac{1.006}{0.0095} = 105.6 \text{ or } \omega t = 89.45° \text{ when } q_1 \text{ is a maximum.}$$

Hence,

$$\text{Maximum } q_1 = B\,\frac{1.006 \sin 89.45° + 0.0095 \cos 89.45°}{3.605}$$

$$= 0.2790\,B.$$

and $q_1 = 0.2790\,B \sin (\omega t + 0.55°)$

Substituting for B its value, $\dfrac{A}{4.606 \times 0.809}$, and changing to coulombs per mile gives

$$q_1 = 0.2790\,\frac{A \times 161{,}000}{4.606 \times 0.809 \times 9 \times 10} \sin (\omega t + 0.55°)$$

$$= 1.339 \times 10^{-8}\,A \sin (\omega t + 0.55°) \text{ coulombs per mile.}$$

Hence $q_2 = 1.316 \times 10^{-8}\,A \sin (\omega t - 120°)$ coulombs per mile.
$q_3 = 1.339 \times 10^{-8}\,A \sin (\omega t - 240.55°)$ " " "

The next step is to get the quantities on each wire with the center wire grounded. Assuming that the potentials remain balanced, the voltages from wires to ground will be

From wire 1..... $\sqrt{3}\,A \sin (\omega t + 30°)$
" " 2..... 0
" " 3..... $\sqrt{3}\,A \sin (\omega t - 270°)$

Digitized by Google

Carrying, as before, the unit charge from wire 4 to wire 1:

$$\sqrt{3}\,A \sin(\omega t + 30°) = 2 \times 2.303 \left(q_1 \log_{10} \frac{600}{0.1288} + q_3 \log_{10} \frac{58}{9} + q_3 \log_{10} \frac{50.8}{9.0}\right)$$

$$0 = 2 \times 2.303 \left(q_1 \log_{10} \frac{58.0}{9.0} + q_2 \log_{10} \frac{65.6 \times 12}{0.1288} + q_3 \log_{10} \frac{58.0}{9.0}\right)$$

$$\sqrt{3}\,A \sin(\omega t - 270°) = 2 \times 2.303 \left(q_1 \log_{10} \frac{50.8}{9.0} + q_2 \log_{10} \frac{58}{9.0} + q_3 \log_{10} \frac{600}{0.1288}\right)$$

Let $B = \dfrac{\sqrt{3}\,A}{2 \times 2.303 \times 0.809}$

Then,

$$\begin{aligned} B \sin(\omega t + 30°) &= 4.534\,q_1 + q_2 + 0.929\,q_3 \\ 0 &= q_1 + 4.680\,q_2 + q_3 \\ B \sin(\omega t - 270°) &= 0.929\,q_1 + q_2 + 4.534\,q_3 \end{aligned}$$

Solving:

$$q_1 = 0.2209\,B \sin(\omega t + 21.12°)$$

$$q_2 = \frac{\sqrt{3}\,B}{23.57} \sin(\omega t - 120°)$$

$$q_3 = 0.2209\,B \sin(\omega t - 261.12°)$$

Substituting the value of B and changing to coulombs per mile, the equations become

$$q_1 = 0.2209 \frac{A\sqrt{3} \times 161{,}000}{4\,606 \times 0.809 \times 9 \times 10^{11}} \sin(\omega t + 21.12°)$$

$$= 1.061 \times 10^{-8} \sqrt{3}\,A \sin(\omega t + 21.12°)$$

$$q_2 = 0.353 \sqrt{3} \times 10^{-8} A \sin(\omega t - 120°)$$

$$q_2 = 1.061 \times 10^{-8} \sqrt{3}\,A \sin(\omega t - 261.12°)$$

Digitized by Google

Having obtained the quantities on each wire under these two conditions, the next step is to determine the values to be assigned to each of the six condensers. Denote these values by x, y, z, and w as shown in Fig. 3 A. Let q_1 be the charge on wire A, q_2 the charge on wire B and q_3 the charge on wire C. The potentials to ground will then be

$$V_1 = A \sin \omega t$$
$$V_2 = A \sin (\omega t - 120°)$$
$$V_3 = A \sin (\omega t - 240°)$$

and the potentials between wires will be

$$V_{1,2} = \sqrt{3}\, A \sin (\omega t + 30°)$$
$$V_{2,2} = \sqrt{3}\, A \sin (\omega t - 90°)$$
$$V_{3,1} = \sqrt{3}\, A \sin (\omega t - 210°)$$

The quantity in any condenser is equal to the capacity of that condenser multiplied by its voltage. The quantity on any wire is equal to the vectorial sum of the quantities on the three condensers connected to that wire. Hence;

$$V_{1,2}\, y + V_{1,}z + V_{1,2}\, w = q_1$$

Substituting,

$$y\ \sqrt{3}\, A \sin (\omega t + 30°) + z\, A \sin \omega t + w\ \sqrt{3}\, A \sin (\omega t - 30°) = 1.339 \times 10^{-8}\, A \sin (\omega t + 0.55°)$$

As this equation is true for all values of ωt, it must hold when $\omega t = 0$.

Then $$y\,\frac{\sqrt{3}}{2} - w\,\frac{\sqrt{3}}{2} = 0.01284 \times 10^{-8}$$

or $$y - w = 0.01485 \times 10^{-8} \qquad \textbf{(A)}$$

When $\omega t = -30°$

$$-\frac{z}{2} - 1.5\, w = -1.339 \times 10^{-8} \times 0.4917$$

or $$z + 3\, w = 1.317 \times 10^{-8} \qquad \textbf{(B)}$$

In the same way,

$$V_{2,1}\, y + V_2\, x + V_{2,3}\, y = q_2$$
$$y\,\sqrt{3}\, A \sin (\omega t - 150°) + x\, A \sin (\omega t - 120°) + y\,\sqrt{3}\, A \sin (\omega t - 90°) = 1.316 \times 10^{-8}\, A \sin (\omega t - 120°)$$

Digitized by Google

When $\omega t = 210°$,

$$1.5\,y + x + 1.5\,y = 1.316 \times 10^{-8} = 3\,y + x \qquad \text{(C)}$$

With the centre wire grounded,

$$V_{1,2}\,y + V_{1,2}\,z + V_{1,3}\,w = q_1$$
$$(y + z)\ \sqrt{3}\,A \sin(\omega t + 30°) + w\ \sqrt{3}\,A \sin(\omega t - 30°) = 1.061\ \sqrt{3}\,A\ 10^{-8} \sin(\omega t + 21.12°)$$

When $\omega t = -30°$,

$$-\frac{\sqrt{3}}{2}\ w = 1.061 \times 10^{-8} \sin(-8.88°) = -0.164 \times 10^{-8}$$

or $$w = 0.189 \times 10^{-8} \text{ farads per mile.}$$

Substitute in (**A**) $y = 0.189 + 0.015 = 0.204 \times 10^{-8}$ Farads per mile.

Substitute in (**B**) $z = 1.317 - 0.567 = 0.750 \times 10^{-8}$ Farads per mile.

Substitute in (**C**) $x = 1.316 - 0.612 = 0.704 \times 10^{-8}$ Farads per mile.

These are the values for the individual condensers, to be connected as shown in Fig. 3A.*

Derivation of General Formula for Calculating the Capacities

After substituting B, in the equations, for (?) A, they have the following form: (for the ungrounded case)

$$a\,q_1 + q_2 + d\,q_3 = B \sin \omega t$$
$$q_1 + c\,q_2 + q_2 = B \sin(\omega t - 120°)$$
$$d\,q_1 + q_2 + a\,q_3 = B \sin(\omega t - 240°)$$

Solving these equations gives

$$\text{(A)}\ q_2 = \frac{(a + d + 1)}{(a + d)\,c - 2}\ E \sin(\omega t - 120°)$$

$$\text{(B)}\ q_1 = \frac{B}{2\,(a - d)\ [(a + d)\,c - 2]}$$

$$[(2\,a\,c + d\,c + a - d - 3) \sin \omega t + (a - d - d\,c + 1)\ \sqrt{3} \cos\ \omega t]$$

*Because of the large number of calculations to be made, the preceding work was shortened by means of the following formulas.

Digitized by Google

With the center wire grounded,

$$\begin{aligned} a\,q_1 + q_2 + d\,q_3 &= B \sin(\omega t + 30°) \\ q_1 + c\,q_2 + q_3 &= B \sin 0 - 0 \\ d\,q_1 + q_2 + a\,q_3 &= B \sin(\omega t - 270°) \end{aligned}$$

from which,

$$(\mathbf{C})\quad q_1 = \frac{B\sqrt{3}}{2(a-d)\,[(a+d)c-2]}\,[\sqrt{3}\,(a\,c-1)\sin\omega t + (a\,c - 2\,c\,d + 1)\cos\omega t]$$

By differentiating (**B**) and (**C**) with respect to ωt, to get maximum q_1, equations of the following form are obtained:

$$\begin{aligned} q_2 &= M\,A \times 10^{-8} \sin(\omega t - 120°) && \text{(From (A))} \\ q_1 &= N\,A \times 10^{-8} \sin(\omega t + \alpha°) && \text{(From (B))} \\ q_1 &= P\,A \times 10^{-8} \sin(\omega t + \beta°) \times \sqrt{3} && \text{(From (C))} \end{aligned}$$

From these, by the method previously given, is obtained:

$$y - w = \frac{2}{\sqrt{3}}\,N \sin\alpha \qquad 3\,y + x = M$$

$$z + 3\,w = 2\,N \sin(30° - \alpha) \qquad w = \frac{2}{\sqrt{3}}\,P \sin(30° - \beta)$$

which are easily solved for x, y, z, and w, giving the values to be assigned to the different condensers.

ACKNOWLEDGEMENT

The writer wishes to express his thanks to Messrs. P. N. Nunn, Markham Cheever, C. S. Ruffner, Edward Bennett and L. N. Crichton (all formerly with the Telluride Power Company) who made the construction of the line possible and who gave very valuable assistance during the work.

BIBILOGRAPHY.

1. M. I. Pupin, "Propagation of Long Electrical Waves". TRANS. A. I. E. E., Vol. 16, 1899, pages 93-142.

2. M. I. Pupin, "Wave Transmission over Non-uniform Cables and Long Distance Air Lines." TRANS. A. I. E. E., Vol. 17, 1900, pages 445-513.

Digitized by Google

3. W. S. Aldrich and W. G. Redfield, "Performance of an Artificial Forty-Mile Transmission Line." TRANS. A. I. E. E., Vol. 18, 1901, page 339.

4. J. H. Cunningham, "Design Construct on and Test of an Artificial Transmission Line." TRANS. A. I. E. E., Vol. 30, 1911, page 245.

5. J. H. Cunningham and C. M. Davis, "Propagation of Impulses over a Transmission Line." TRANS. A. I. E. E., Vol. 31, 1912, page 887.

6. A. E. Kennelly and B. Tabossi, "Artificial Power Transmission Line". *Electrical World*, Vol. 59, Feb. 17, 1912. p. 359.

7. A. E. Kennelly and F. W. Lieberknecht, "Measurements of Voltage and Current over a Long Artificial Power-Transmission Line at 25 and 60 Cycles per Second." TRANS. A. I. E. E., Vol. 31, 1912, page 1131.

8. G. S. Humphrey, "The Charging Currents of Three-Phase Transmission Lines." *Elect ical World*, Vol. 58, Nov. 1911, page 1300.

9. E. B. Rosa and F. W. Grover, "The Absolute Measurement of Capacity." *Bulletin of the Bureau of Standards*, Vol. 1, 1905, p. 153.

10. E. B. Rosa, "The Self and Mutual Inductance of Linear Conductors." *Bulletin of the Bureau of Standards*, Vol. 4, 1908, p. 301.

11. E. B. Rosa and Louis Cohn, "Formulae and Tables for the Calculation of Mutual and Self Inductance of Coils." *Bulletin of the Bureau of Standards*, Vol. 5, 1908.

Digitized by Google

Digitized by Google

To be presented at the 333rd Meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 8, 1917.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

INDUSTRIAL RESEARCH AND THE COLLEGES

BY A. E. KENNELLY

ABSTRACT OF PAPER

An outline of the proper relationship that should exist in the industrial research field between the pure science college, the technical college and the industries, themselves.

IN ANY general discussion on the influence of research on the development of electrical industries, the share of the colleges in this influence deserves to be formulated and defined. The more clearly we can realize the ways in which the colleges can assist in this work, and the more closely we can agree upon the methods by which this assistance can be rendered, the more likely we are to be able to bring about the result desired. In what follows, certain propositions are ventured, in the hope of eliciting discussion, and of thereby reaching a consensus of opinion.

To begin with, it will probably be admitted that industrial research is scientific investigation directed economically towards improvements in production.

It has been known for centuries that discovery and invention have made the fountainhead of new industries. For example, it is said that the starting point of the wealth of Holland, and in the seventeenth century, the Dutch republic was the first exporting country in the world—was due to the discovery by the Dutch fishermen, on their remote islands, of a process of preserving fish for storage and transportation. Moreover, throughout all industrial history, men have devoted their time and labor to inventing or designing improved processes in manufacture. Industrial research, in a broad sense of the term, has therefore been at work ever since industry existed. The difference between industrial research in the modern sense, and in the mediaeval sense, lies in an emphasis upon applied science, and upon the application of scientific methods. Under the mediaeval regime, industry was understood to be handicraft. Individual skill in handicraft was aimed at, through the manual

Digitized by Google

training of apprentices by master workmen. Improvements in production had to come slowly, through the gradual development of skill in successive generations of workmen and apprentices.

The advent of the steam engine and of steam-driven factory machines, overthrew, as we all know, the processes of production. These became mechanically stereotyped. The province of individual manual skill changed to the design, direction and management of machinery. The charm of individuality in specially skillful workmanship had to be relinquished, in favor of the enormously increased and standardized production of the humanly guided machine. Under the new conditions, mechanical or chemical improvements could be introduced much more easily, partly because of the absence of intellectual inertia in the producing machinery, and partly because of the more definite predetermination and regularization of machine-made over hand-made products.

The introduction of industrial research in the recent and more restricted sense, has come about partly materially through the opportunity provided by large-scale mechanical or chemical processes, and partly psychologically through the change in the general attitude of mind towards applied science. Formerly, there was an attitude of distrust towards scientific training in industry. Now it is coming to be realized that in all industry, applied science can be made to pay. In fact, it is coming into general apprehension, that sooner or later any industry will be outdistanced competitively, unless maintained not only by eternal vigilance, but also by eternal scientific study.

The part of the colleges has been and is to train young men to learn a business studiously and to carry it on systematically. In the colonial days, the colleges educated men almost exclusively for the professions. Today, the men educated in the colleges enter general business in as great numbers as they enter the professions.

The non-technical scientific departments of the colleges and universities include such fundamental subjects as mathematics, physics and chemistry. The duties of these departments of so-called pure-science *i.e.* science contemplated apart from applications, are two-fold; namely

(*a*) Teaching, by carrying on instruction of the students in those sciences.

(*b*) Learning, by carrying on researches in those sciences.

Digitized by Google

The teaching and the learning have to be carried on interdependently and perpetually.

It is probably undesirable that the pure-science departments of the colleges and universities should continuously undertake industrial research. There is nothing in their work to prevent their teachers or students from undertaking such research. Many on their staffs are excellently qualified for conducting industrial research; but there is so much other important work to be done, which these departments are alone able to do. In all times, the progress of the sciences has been largely left to the college teachers of those sciences. Physics and chemistry are subdivided into so many branches, that no one man can do justice by his efforts to more than a very small number of studies. There is a limitless field of undreamed of knowledge everywhere along these various lines. The expenses of modern scientific laboratories are so great, that few private individuals can expect to conduct researches in pure science, and the instructing staffs in the college laboratories have special facilities for experimental work. The bulk of new scientific material, on which industries may ultimately depend, has to be worked out and discovered in the pure-science laboratories of the world. Again, mathematics is a science covering a range of knowledge, thought and inquiry, so vast that no one mind can compass it, and yet its knowledge is woefully backward and deficient, even for purely utilitarian purposes; so that there are immense fields to be developed, even on the unlikely hypothesis that no new general discoveries will be forthcoming. Of the indefinitely great number of mathematical functions that may be mentally reviewed, only a few dozens have yet been tabulated and arranged for practical use. The progress of knowledge in mathematics is far less restricted to the college faculties, than the progress of subjects like physics or chemistry; because the necessary plant is so inexpensive,—white paper, black pencil and grey matter—yet even here the influence of the college atmosphere for mutual teaching and learning is relatively so productive, that a large share of the world's mathematical pioneer work emanates from the colleges.

While, therefore, under extraordinary circumstances, such as those due to the present World-German war, the pure science departments may advantageously take up industrial research; yet, as a general rule, the best contribution of those departments to industry is by restricting their attention to pure science.

When we come to the engineering and technical colleges, or

Digitized by Google

to corresponding university departments, the opportunities for their sharing in industrial research are greater. In the first place, they train men directly for work in applied science, and, in the second place, their contact with manufacturing industries is greater. By comparison with the pure-science departments, their field of activity is, on the one hand, intellectually narrower; but on the other hand, they come into closer relations with the needs and problems of industries. The applied-science college laboratory staffs are very frequently occupied on engineering and constructive problems of the industrial world. Such activities are valuable, both to the colleges and to the industries, provided that the amount of industrial research work undertaken does not swamp the regular teaching. There are various ways in which the technical colleges can assist in industrial research, and among them the following:—

(1) Training industrial-research investigators to go out into the industries.

(2) The taking up of particular industrial-research problems by particular members of the laboratory staffs, under individual private agreement with industrial concerns, the work being carried on in the college laboratories.

(3) The same as in (2): but with the work carried on in the workshops of the industrial concerns, instead of in the college laboratories.

(4) By the industries formulating their problems directly to the college as a corporation, and entering into an agreement for the maintenance of research work, in the college laboratories or elsewhere, towards the solution of those problems.

All of the above methods are in vogue, as well as various combinations of them. Each has its particular advantages and disadvantages, in view of the conditions of any individual case. So long as the total amount of industrial research work carried on in a technical college does not exceed a certain amount, depending on the size of its plant, it is not very important as to which method is followed. Where, on the contrary, the total demand for such industrial work exceeds that limit, it becomes a serious problem as to how it should be conducted, not only from the standpoint of the college; but also from the standpoints of the industries and of the public.

The only essential difference between scientific researches carried on for an industry, and general scientific researches carried on without reference to any industry, is that the former

Digitized by Google

are expected to bring in results of economic value, and must therefore be safeguarded by secrecy, while the latter, being expected to bring in results of scientific and engineering value only, naturally demand publication so far as they are successful. It is manifest that no industry could afford to undertake research, unless it expected the results to pay a profit on the expense, and such profits would be jeopardized if the successful results were communicated to competitors. The watchword of industrial research is therefore loyalty to the industry, which makes the venture in investigative effort, and this entails watchful protection as to the secrecy of the investigation and its results.

So far as the large industries are concerned, they install their own experimental laboratories, and employ their own experimental investigators. It is natural and proper for them to protect the results of their inventive and experimental efforts, either by patents or by concealment, as may best suit the industrial need. The colleges can best serve these auto-research concerns, by supplying them with well trained graduates. The difficulties lie in the paths of the smaller industrial concerns, which desire to make progress by scientific effort and systematic study, but which cannot afford the expense of a special private research department. These younger industries must have recourse either to the services of a consulting specialist of the researcher type; or to the services of some specialist college laboratories.

The call of the younger industries on the technical colleges for help, is one which the colleges naturally desire to meet, so far as they can do so without disrupting their regular work of teaching and learning. On the other hand, the task is rendered difficult by the need for secrecy, and for the discrimination in dealings which that secrecy may involve. The whole atmosphere of any healthy college is one of intellectual freedom. The ideas and knowledge of any individual in the college community are placed at the academic disposition of all of the rest who may be inquisitively inclined. A recognized exclusive monopoly of information or knowledge must interfere with the best qualities of any institution of learning. Consequently, the maintenance of any considerable amount of industrial research in a college becomes a burden and a difficulty. For this reason, either method (3) or a combination of methods (3) and (4) is perhaps the best for a technical college to follow, when a considerable amount of technical research is desired to be undertaken for

Digitized by Google

those industrial concerns which are not in a position to maintain their own research laboratories.

In the long run, therefore, it seems most desirable that the technical colleges should always carry on general researches in their laboratories, of such a nature as may advance applied science, stimulate careful observation on the part of students, contribute to the published fund of available technical information, supply new knowledge to the teaching staffs, and train students for entering industrial research. To this end, research fellowships and research endowments are of the greatest aid both to the colleges and to the industries. A limited amount of industrial research work may also be advantageously carried on in the college laboratories, along with the general research work. As, with the growth of new industries, more and more demand for such industrial research comes to the colleges, the desirability increases of dealing with it in a systematic way, through the college as a corporate body, by maintaining, in the workshops of the industrial concerns, special assistants under the direction of specialists on the teaching staff. In this way, perhaps, the most effective service may be given by the technical colleges to the junior industries, with the maximum of economy. It may not be too much to expect that, as time goes on, the junior industries may lean more and more upon the technical help of the colleges, without having to enter into any mutual agreement or combination, in order to avail themselves of such aid.

Reference has been made above to the continuous duties of a college, both as to teaching and learning. A third important duty also exists, although its influence on industrial research is less direct; namely, the maintenance and propagation of ideals, or of those underlying habits of thought and action which are sometimes summed up as "character", and at other times are referred to as the working philosophy of life. Colleges foster and transmit such ideals, more or less unconsciously perhaps, to those who study within their walls, partly by tradition, partly by contact between teachers and pupils, partly by the study of history, philosophy and a host of other horizon-enlarging subjects, and partly by the interchange of student opinions. The transmission of such subconscious motives may not have direct bearing upon the technical attainments of college trained men, and many men who have never gone to college are actuated by ideals as fine as those which any college can claim, nevertheless, the indirect stimulating effect of such ideals on the college-

Digitized by Google

trained researcher is manifest to the careful observer on every hand.

An ideal international system would be one in which the pure-science colleges should lay the foundations of future industries by enlarging and disseminating the world's knowledge of the basic scientific principles, the technical colleges should do the same for applied science, while at the same time taking a share in the economic applications of science to industry. The industries themselves should undertake their own researches, under the guidance of qualified research specialists. Vocational schools would train industrial foremen in the elements of the same principles of science, art, technique, economy, thrift and hard work, as applied to those particular industries in which each nation, is, by its peculiar circumstances, specially adapted to excel.

Digitized by Google

Digitized by Google

To be presented at the 333d meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 8, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

INDUSTRIAL RESEARCH AND ITS RELATION TO UNIVERSITY AND GOVERNMENTAL RESEARCH

BY C. E. SKINNER

ABSTRACT OF PAPER

1. Introduction emphasizing the great activity in all branches of research at the present time.
2. A division of research activities into three principal classes, university, governmental and industrial.
3. A statement that the principal function of university research should be to train research men and some suggestions as to the type of training required.
4. A brief statement of the function of governmental research which has to do with such things as the development and conservation of our natural resources, the national defense and the promotion of those things which are for the benefit of the whole people.
5. A brief description of the Research Division of the Westinghouse Electric & Manufacturing Company, its rise and its relation to other departments.
6. A statement of the desirability of co-operation among all agencies engaged in research.

RESEARCH has been defined as "diligent protracted investigation, especially for the purpose of adding to human knowledge." If we accept this definition we find that it covers an extremely wide field of activities. It applies equally well to the work of the pure scientist, whose primary aim is to extend our knowledge to the remotest bounds of the universe, and to the work of the industrial chemist, who by careful painstaking analyses maps out the limits of impurities which may be allowed in a manufacturing process. Between these extremes lie possibilities for research in every imaginable field, with pure and applied science so closely interlinked that it is impossible to say where the one ends and the other begins.

That there are possibilities of adding to human knowledge in innumerable ways, is evidenced by the status of research today. Never before were there so many interested in research in all its branches; never before were there so many forces at work to promote research. Changing economic conditions, even before the war now in progress, made it necessary that research be

Manuscript of this paper was received September 19, 1917.

Digitized by Google

carried on in almost every field of endeavor. The war has emphasized this necessity many fold. Many industrial corporations which were not provided with research facilities heretofore are making such provision and many of those having such facilities are making considerable additions, both for increased amounts and for an increased variety of research. Research departments and scholarships are being provided for in universities and colleges. Commercial research laboratories are being promoted to serve groups of industries where individually they cannot economically provide their own facilities. Scientific and engineering organizations are appointing research committees, and research organizations, such as the National Research Council, are being formed. We have research provided for by private gifts and by governmental grants. The Federal Government is constantly increasing its research facilities in its various departments, such as the Bureau of Standards, the Bureau of Mines, the Forest Products Laboratory, the Agricultural Experimental Stations, etc. This movement is not only national; it is international. Commissions from abroad have studied research conditions in the United States and the United States have sent men to our Allies to study their progress in research in connection with the war. For the immediate present, progress in pure scientific research is perhaps much less than prior to the war, but nevertheless the status of research today is a condition of great activity. The slowing up of pure scientific research at this time is due to the fact the workers the world over are in a very large measure engaged either in actual warfare or in research in connection with problems arising through the war. Fortunately for the future, many of the results of these war investigations will be of great value in connection with the peaceful pursuits to come after the war.

What vast fields for investigation are opened up by the problems relating directly to the war! These are physical, chemical, electrical, metallurgical, physiological, psychological, mechanical, medical, problems of undersea noises, problems of high altitudes, problems in wave propagation, problems in medicine, in surgery, food values, agriculture, transportation, and a host of others. It is merely the hundredth repetition to say that the present war is one of scientific methods and machinery, but this repetition emphasizes the place which research now necessarily occupies and will occupy after the war. It should be of value therefore to discuss some of the phases of the problems of research

Digitized by Google

as a whole and especially industrial research and its relations to other lines of research.

For the purpose of this discussion, research may be conveniently divided into three,—possibly four—general classes; this division depending upon the agencies involved and the purposes for which the work is done. These are university research, industrial research, and governmental research,—and possibly philanthropic research. The first includes the pure scientific research, which naturally finds its home in the university, and all other research done there for the purpose of training men. The second includes all that done by industrial concerns or for them with the purpose of advancing industry. The third includes all that carried on by the Federal or the State Governments for the purpose of benefiting the people as a whole. Philanthropic research differs from governmental only in the fact that its funds are provided by individuals, instead of by the Government, as for example the work of the Rockefeller foundation. No sharp dividing lines can be drawn between these classes. They all have much in common. All should be scientific. Much industrial research is philanthropic, and many times university research leads to industrial progress. Governmental research is for the purpose of serving the whole people and it therefore does much for education and for industry and certainly could be classed as philanthropic. It is just as difficult, therefore, sharply to maintain these classifications as it is to maintain a clear-cut distinction between pure and applied science, as has been so well discussed by Past-President Carty in his presidential address.

It may be well, however, to consider something of the primary function of each of these four classes, their distinctive fields and their relation to each other. The discussion which follows naturally will be from the viewpoint of one whose experience lies wholly within the field of industrial research.

The primary function of the university in research should be the training of research men. If the conditions outlined in the introduction of this paper are accepted, then it is evident that men with the broadest and best training possible are going to be required in ever increasing numbers for every possible phase of the work. It is self-evident that the fundamental training of these men must be gotten in the university and universities should be equipped to turn out research men just as they are now equipped to turn out men with academic and engineering degrees. It is to the university we must look for the broad fundamental

Digitized by Google

training so necessary in research. These trained men will in accordance with their training and their fitness find their places in pure scientific research, in industrial research, in governmental research and in teaching positions where more and more research men are to be trained. In this connection it is rather a sad commentary that the university has not been able to make its teaching positions more attractive by providing compensation more in line with that obtainable in other lines. While writing this paper, its author received letters of inquiry for several men for teaching positions,—some in connection with research—with specifications which could be met only by men of considerable experience. The compensation named was very much less than that which meeting the same specifications could command in other lines. While it is generally understood, at least by those outside the teaching profession, that it has many compensations, such as short hours and long vacations, the average salary is certainly not one of these special attractions. We have splendid endowments for buildings and sometimes for equipment, but we have practically no endowment for men of genius who might make notable progress in pure research and at the same time serve as teachers and examples for the training of men for the whole field. If it takes a genius to recognize a genius yet undeveloped and properly to stimulate and direct that genius, how necessary it is that we place men of genius at the head of the research departments of our universities. A few are already so equipped, but this is a plea for a larger and a more definite program of research training and the development of that judgment which will be able to direct these trained men to the line of work for which they are best suited.

In training research men, the university will naturally become the custodian and the promoter of pure scientific research. Properly equipped and properly manned, here as nowhere else can go on with ever increasing acceleration that wonderful work leading to the discovery of new elements, new laws and new phenomena. It is here that studies can be made of phenomena which are of absorbing interest, but which apparently have no commercial value whatsoever. It is here that we must look for studies of such things as the photoelectric effect, the penetrating power of alpha, beta and gamma rays, the character of the emanations of radium, the study of vortex action, and a thousand other studies,—all of which have value in advancing our knowledge of the unknown. All have value in the training of men and

Digitized by Google

it may not be too much to say that all will ultimately be of value in advancing the well being of the human race. Contact with pure scientific research of this kind is of the utmost value to the research worker in whatever field if for no other reason than the stimulus it gives his imagination, and a research worker without imagination is sure to be a failure.

In the training of research men facilities and problems must be provided and the question arises as to the relation of these problems to going industrial problems. One should not be dogmatic on the subject, but the following suggestions may be worth consideration and discussion. Training should be aimed first at a broad general education. This should be such as to give culture as well as a thorough grounding in general science. Specialization should begin only after the broader foundation is laid. This specialization should be aimed at developing the research spirit, which is simply a desire for knowledge of the truth. To this end problems should be set which will develop the latent abilities to observe facts and to overcome obstacles. For such training the exact problem matters little just so it is in the field of chosen endeavor. It may be of a highly theoretical nature with no possible immediate industrial application. It may be for the establishment of a law, the proving of a principle or the finding of the limits of a known law. It may be a very restricted problem, as the proving of a single phase of one otherwise well worked out. The problem should be so chosen that the really essential apparatus is available for its solution or the problem should require that the necessary apparatus be devised. It is really curious to see the attitude of different men with regard to apparatus when a problem is set for solution. At the one extreme a worker will demand the most elaborate and accurate apparatus known to the art before he feels that he can begin his work. At the other extreme the worker uses whatever means are at hand or devises crude makeshift apparatus. The former is interested more in his apparatus than in his problem; the latter more in the principles involved than in the finish of his instruments. Both may fail,—the first due to too much elaboration of method and apparatus and the second due to the use of apparatus not adequate for the purpose. A part of the desirable training is therefore the training of the judgment as to how little and how simple apparatus can be used and still cover all the necessary points in research. The maximum of success often comes to the worker who uses the simplest apparatus both as to the time

Digitized by Google

required to get results and their values. It is of course impossible in many cases to get the required results without the use of the most accurate and delicate apparatus available. Larger and more accurate telescopes make new discoveries possible and more sensitive oscillographs give accurate wave forms whose existence would not even be discovered by less sensitive apparatus.

Industrial research problems cannot as a rule be given over to university research departments for solution. There are many reasons for this,—the patent situation being one of the prominent ones. So long as industry depends so much upon patents or upon secret processes for the protection of its business it must carry on its vital research within its own laboratories and under its own control. Many industrial problems are also so closely related to the work daily being performed in producing the particular commodity that any research in connection therewith must be done on the ground and by men familiar with all phases of the problem.

There are, however, many problems which could be turned over to university research laboratories for solution and these would be very valuable for the training of men for the industry. These are problems having to do with such things as methods of measurement or fundamental laws such as the laws of heat transferrances or the laws of hysteresis.

There should be much closer co-operation between the university and industrial research. Industry should recognize that it must depend primarily upon the universities for its trained research men and co-operate to the fullest possible extent to the end that properly trained men be turned out. Pure scientific research should be recognized as the legitimate field of work of the university. The application of science to industry should be recognized as the field of the industrial research organization and it should be realized that no sharp dividing line can be drawn between the two. The university should do research primarily to train men, and the industry to ensure dividends to its stockholders.

Governmental differs from industrial research mainly in the fact that it is financed and directed by the Government and its results should therefore be directly available to all the people. It has many and varied fields such as those relating to the development and conservation of our resources, the national defense and the establishment of standards of weights and measures.

Digitized by Google

Much governmental research is undertaken for the benefit of industry in general and its methods and equipment are necessarily much the same as those used in connection with industrial research. Like industrial research, it must look to the university for the training of its men. As in industry the present war has brought very greatly increased demands on our governmental research departments and has also shown the desirability of increased cooperation between all the forces having to do with research, both at home and abroad. Here again it is difficult to draw a sharp dividing line between the work to be undertaken by the Federal or the State Governments and that which should be left to industry or to the university. It is safe to say, however, that as in other lines research carried on by the Government will increase in amount and in the kinds of work undertaken, and that, further, there will be increased co-operation with other agencies carrying on research.

While philanthropic research has been mentioned as a possible class, its function and relation to the other classes mentioned are so obvious that it will not be further discussed here.

Industrial research has been described as having for its primary function the securing of dividends to the industry. Fortunately for those engaged in it, its ideals can be just as high as those of pure scientific research, for its work usually results in direct and lasting benefits to mankind. This is certainly true of those researches which have given us commercial wireless telegraphy, transcontinental telephony, half-watt incandescent lamps, giant turbo-generators, modern tool steel and a host of other things.

No single description will apply to the rise of research departments in different industries. In the older industries, the early work was usually carried on by more or less "rule of thumb methods" with a certain amount of experimentation directly on the product. Later, test laboratories were established, and finally these were either combined into a research department or a separate and distinct research department was formed to take care of the necessary research work. In many of the newer industries, the foundation on which the industry has been built is the result of research, and in such cases research work is almost always continuously maintained throughout the life of the industry. This is particularly true of our chemical and electrochemical industries.

In most industries having research departments, we can trace their rise from the beginning of the work, even though done

Digitized by Google

under the guise of test work and experimental work and without any thought of its being research in the sense of the present use of the term. This is particularly true of the specific industry and organization with which the writer is connected.

It is impossible to describe the rise of research in the Westinghouse Electric & Manufacturing Company without giving something of the part taken in it by the great founder of the company,—Mr. George Westinghouse. A critical study of his life work will show that he personally carried on research of a very high order and in many fields. In his personal work, however, Mr. Westinghouse rarely used ordinary laboratory methods. His experimental work was done full size scale. If he was interested in a rotary engine he did not build a model, he built an engine to suit the commercial conditions he had in mind. If interested in the development of producer gas no mere laboratory experiment would suffice; he built a complete producer gas plant. His work on the development of air brakes, switches and signals, the steam turbine and many other devices was all conducted in the same way. He was an experimental rather than an analytical research worker. He undoubtedly had many failures in his experimental work, but the commercial success of the companies which bear his name shows that in the end the balance was very greatly in his favor. The foundation of each was largely his own personal work. This type of experimental work to be successful requires a breadth of vision, a soundness of judgment, an optimism and a dynamic energy to carry it forward, which are possessed by but few men. Without these qualities so abundantly possessed by Mr. Westinghouse, research work done in his characteristic way is more liable to lead to failure than to success. Throughout his active life Mr. Westinghouse always had in hand a number of investigations of the type referred to and only those who have had the good fortune to work in close contact with him can appreciate the amount of thought, energy and attention to detail which he gave to all of his experimental work. It was characteristic of him that he so drove his work that he would get results in days where the average worker would require weeks or months.

He early recognized the merits of the alternating-current system of distribution and personally gave much attention to its development in the formative period. This system he pushed to a commercial success, overcoming all obstacles including attempts at legislation against the use of alternating current in

Digitized by Google

many states. Not the least of his triumphs in connection with this system was the lighting of the World's Columbian Exposition in 1893 using a type of incandescent lamp necessitated by the patent situation which was considered by nearly every one familiar with the subject as a hopeless substitute for the then accepted type. The modern history of alternating current and its place in the electrical field today is too well known to merit further comment.

At a very early age Mr. Westinghouse became interested in the rotary engine and he carried on experimental work in the development of the rotary engine continuously for many years until the advent of the steam turbine. He immediately recognized the merits of the turbine principle and casting aside the work of half a lifetime on the rotary engine he at once transferred his allegiance and his energy to the steam turbine, with the result that the steam turbine has become the predominating prime mover in connection with the use of steam today. He was the first to combine the alternating-current generator and the steam turbine in large units,—these being the forerunners of the giant 70,000 kv-a. turbo-generators of today. In passing it may be said that the development of the turbo-generator to its present state of perfection is perhaps one of the most notable pieces of research work in modern times and while the finished result is the combined work of many minds very much of the initiative can be ascribed to the personal work of Mr. George Westinghouse. Both the steam turbine and the turbo-generator are so different in type, construction and all essential details from the reciprocating engine and the slow-speed alternator that all previous experience had to be cast aside in the development of these machines. The problems of ventilation, insulation, stresses in materials, and many others had to be studied from entirely new angles. Experimental units as large as 10,000 kv-a. have been built for the sole purpose of studying the best method of ventilating turbo-generator units.

While much research of the kind carried on by Mr. Westinghouse is still necessary in the development of the company's product it is coordinated with an analytical study of all the data available and supplemented by research in the laboratory, the factory and the field. The laboratory was early recognized as a necessary part of the engineering equipment and several were provided for different purposes in which much research was done. The present organization has resulted from the combining of

Digitized by Google

these laboratories and certain other activities into a division of the engineering department to which additional facilities for research have been added from time to time. Being a part of the engineering department and working in close cooperation with the works department the organization provides for the most intimate possible contact with the problems and requirements of the business and for the most direct applications of the results of research.

The research division is divided into sections and embraces work from the purely theoretical side of the problems presented to the practical application of principles and materials in the factory and in the field. It has under its control various laboratories, such as an electrical laboratory, a process laboratory, a molded-material laboratory, a materials testing laboratory, a chemical laboratory, a ceramic laboratory and a more recently acquired research laboratory proper especially set aside for the work of a more theoretical nature. This latter laboratory has provision for studies in organic chemistry, electrometallurgy, metallography, illumination, general physics, electrochemistry, insulation, etc., etc. The theoretical and the practical research men while in separate sections of the same unit work in close harmony. The result of a theoretical research, such as the production of a new device or material or the application of a new principle, can be tried in a practical way in another section of the division.

The division does all the engineering in connection with the purchase of materials and carries on the experimental work in connection with the establishment of shop processes. The men working on materials' specifications keep in the closest possible touch with the method of production of these materials, their characteristics, their engineering application and their shop use. The process men work between the engineering department and the shop in connection with processes of every sort and prepare all specifications with the cooperation of the shop men under which the process is carried out. The division has the technical direction of the brass foundry, the scrap recovery plant and the copper refinery and is thus in daily contact with the multitude of metallurgical problems arising in these processes. The control laboratory as well as the theoretical laboratory for these processes being under the direction of the division, the best possible cooperation between the two is ensured.

The above clearly shows that the division has been so organ-

Digitized by Google

ized that it can be a leader in the development of new things and at the same time keep in closest possible touch with their application and use. Problems for solution come to it from every possible direction and not the least fertile source of theoretical problems is the grist of troubles from the daily routine work in the factory. We believe that the research division should both lead and follow the practical end of the work. There should be work going on which has for its object the securing of information or the perfecting of devices which will be required in future years. At the same time old processes should be improved, old devices should be reviewed and new treatments should be provided for old material. Research should lead, should follow and should parallel engineering and factory work. Many times the results of researches cannot be taken advantage of at once and there should be a constant accumulation of information available when it is needed. No research can ever be considered as complete. Each new advance in contemporary lines, whether new instruments, new materials, new methods, new applications or new laws, will make further advances possible though not always profitable.

What of the future of industrial research? What lines will be profitable? Should there be greater centralization and greater co-operation between industrial, governmental and university research? The answers to these questions might well be given with counter-questions. What industrial subject is so far advanced that further advances are impossible? If co-operation is profitable in a single corporation, why should it not be profitable between greater forces. It should be evident from what has gone before that the writer believes implicitly in a constantly increasing field for research in every industry. If we can show advances in any material or process or device by proper research, why should not every industry profit by research. It is not expected that every individual study will be profitable nor that every successful result can be at once applied, but careful painstaking and persistent research should benefit any industry. It is expected of course that the research undertaken will have a direct bearing on the particular industry and not be a study of some unrelated subject. It would hardly be profitable for the steel industry to make an elaborate study of the life history of the yeast plant, but the progress in alloy steels has so profoundly changed many industries in the last few years that further research in this line will surely be of value.

Digitized by Google

It is probable that more and more industries will establish research departments or enlarge their research work (often carried on under some other name) and that these will in a large measure for the present work independently of each other. We must expect competition in this line as well as in other industrial lines. We may confidently predict, however, that we will have an increasingly better general co-operation of all research forces and such agencies as the National Research Council, which bring together for a common purpose men engaged in every phase of research, should have a profound influence on bringing about this co-operation. If such organizations are a benefit in times of national stress and need, surely they can be of similar value in times of peace. The university, the government and industry each has its distinctive field and each needs the cooperation of the others, and only when we secure complete cooperation among all these forces can we make our best advances as an industrial people.

Digitized by Google

To be presented at the 334th meeting of the American Institute of Electrical Engineers, New York, November 9, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

AN EXPERIMENTAL METHOD OF OBTAINING THE SOLUTION OF ELECTROSTATIC PROBLEMS WITH NOTES ON HIGH-VOLTAGE BUSHING DESIGN

BY CHESTER W. RICE

ABSTRACT OF PAPER

The electrodynamic method for obtaining the solution of electrostatic and allied problems is developed to a high degree of accuracy. The method is then applied to the study of high-voltage bushings. An experimental high-air-efficiency bushing was then built and tested with the result that the arc-over was very materially lower than had been anticipated.

A study was then made to ascertain the reason for this large discrepancy, which was found to be due to an unexpectedly large *surface effect* which varied greatly with different materials.

After obtaining the numerical value for the *surface effect* a reasonably accurate predetermination of the arc-over of structures, in which the stress distribution is known, can be made.

In order to determine the desirability of using artificial equipotential surfaces to increase the efficiency of the use of the supporting dielectric, diagrams were taken and a small bushing of this type constructed and tested.

A study was then made to find out whether the reduction in diameter of condenser bushings is principally due to equalization of potential or due the greater strength of insulation when barriers are used. As a result of this work, it is believed that the barrier effect greatly predominates.

A short discussion follows which shows the difficulties of obtaining a sufficiently exact theory of bushing design to enable us to predetermine the most efficient shape for a practical bushing.

A series of small bushings were then made and tested with a view to determining the general shape and characteristics which go to make up a practical all around bushing.

The appendix gives an unexpurgated solution of the following two flow problems.

I. The distribution of the electrostatic field when any two confocal hyperboloids of revolution of one sheet and of the same family are maintained at given potentials.

II. The distribution of the electrostatic field when any two confocal hyperboloids of revolution of two sheets and of the same family are maintained at given potentials.

INTRODUCTION

IN general, a bushing has to serve two purposes; first, it must support the leading-in wire or conductor and must act as a mechanical unit capable of being removed or replaced in case of damage; secondly, it must insulate the high-potential conductor

Manuscript of this paper was received March 9, 1917.

Digitized by Google

from the tank which is usually at zero or ground potential. The leading-in wire, or what may be called the high-voltage electrode may have various shapes. The tank with hole in it may be called the grounded electrode and it may be shaped in various ways. A solid supporting dielectric is necessary to make the structure a mechanical unit, that is, to mechanically connect the high-voltage central electrode with the tank or grounded electrode. Between the grounded electrode and the high-voltage electrode, isolated metallic surfaces may be introduced which will form *artificial equipotential surfaces*. The condenser bushing is a familiar example.

The electrical part of the design consists in studying the electrostatic field distribution between the electrodes in order to use the various available insulating materials to their best advantage. It is obvious that there are large numbers of possible electrode shapes and arrangements, the electrostatic field distribution of which should be studied in order to determine the one which is best adapted for commercial use. The following investigation was undertaken with a view of determining the theoretical possibilities of some of the various possible arrangements. The work was started in July 1914, and extended with short interruptions to July 1916. Naturally an investigation of this nature is never complete but I hope that the work to be described will be of interest to engineers and also stimulate others to take up the work so that eventually we will have a better and more complete understanding of this and similar problems.

Preliminary Work

The preliminary work consisted in investigating the possibilities of obtaining a reasonably approximate solution of the bushing problem. The first question which presented itself was the following: Can two-dimensional fields be rotated and used as satisfactory approximations for three-dimensional problems? In order to test out this matter the literature was searched for a solution of the rod and torus problem, so as to be able to compare it with the solution obtained by rotating the field of two parallel wires. If the approximate solution, as obtained by the rotation of the plane figure, did not prove useful as a result of comparison with the exact solution, it was thought that possibly some simple law of distortion or stretching might be arbitrarily imposed upon the rotating-plane diagram which would change the lines of force and equipotential surfaces so as

Digitized by Google

to closely conform with the accurate three-dimensional solution. If such a procedure was found possible, it was hoped that the same method could be used in transforming the many available two-dimensional problems into approximate solutions of the related three-dimensional figures of revolution.

The problem of insulating two parallel wires was studied in order to compare some of the various criterions which might be advanced for the correct and strongest surface along which to place the insulating material. For this preliminary work the question of different inductive capacities was neglected. The following surfaces were studied by graphical construction on a large sized diagram of the field between parallel wires drawn for equal tubes of electrostatic flux and equal differences of potential.

I. —Constant surface flux density.
Equal areas between lines of flux on equipotential surfaces.

II. —Surface of constant potential gradient.
Equal distances along lines of force between equipotential surfaces.

III.—Surface of constant volume energy density.
Surface defined by unit cells of equal volume.

IV.—Surface such that the component of the potential gradient along the surface has a definite limited value, for example say, 50 per cent of the gradient. The object in studying such a surface is apparent if we assume that the surface of the insulation introduces a weakening effect. For in that case the component of the gradient tangent to the surface must not exceed the breakdown strength of the surface, whereas the actual gradient may be equal to the dielectric strength of the surrounding dielectric.

V. —Surfaces of constant creepage.
Equal distances between equipotential surfaces.

The surfaces defined in I, II and III were seen to be identical as would be expected.

The corresponding surfaces were drawn for the solid figure resulting from the rotation of a right section of the plane figure. Of course, such a procedure does not give the solution of the torus problem, but as explained above it was done in order that the result might be compared with the true solution of that problem.

A search of the literature failed to yield a useful solution of

Digitized by Google

the torus problem. C. L. Fortescue and S. W. Farnsworth[1] state that the smooth lines (in Fig. 4 of the paper) show theoretical equipotential surfaces of indicated potential for the given terminals. Inspection of the figure shows that the smooth surfaces are those cut out by revolving a family of circles about the axis of the rod which would yield a set of anchor rings, the orthogonal surfaces would then be a set of spheres. That this cannot be a solution of the torus problem is stated by W. E. Byerly.[2] "Indeed no possible distribution can make our anchor rings or our spheres a set of equipotential surfaces." It is therefore, evident that their solution and the calculations given in their curves Figs. 13, 14, 18 and 19 must have been the result of some sort of an approximation. It seems to me that a discussion would have added to the interest and clearness of their paper.

A study of the solution of the torus problem, as outlined by Byerly and also given by Hicks,[3] convinced me that the difficulties of calculating sufficient points for the construction of a diagram of the field would be very great, and even if the solution were available, it would not be of great assistance in solving the bushing problem because the rod and torus does not constitute a self-supporting structure resembling a bushing. It was realized, at this time, that if the solution of an infinite rod passing perpendicularly through a hole in a plane were available, it would be of considerable value as this would constitute the simplest form of bushing.

As a result of this preliminary work, the difficulty of obtaining even approximate mathematical solutions of such electrostatic problems was brought out.[4]

Various experimental methods were, therefore, looked into with the hope of obtaining a method which would enable us to obtain experimentally the solution of any desired electrostatic problem.

---

1. "Air as an Insulator when in the Presence of Insulating Bodies of Higher Specific Inductive Capacity." A. I. E. E. TRANS., 1913, Vol. XXXII, Part I, p. 893.

2. Fourier's Series and Spherical Harmonics page 265.

3. Toroidal Functions, Philosophical Transactions of the Royal Society, Part III, pages 608–562, 1881.

4. In this connection it is interesting to read what Maxwell has to say about such problems; Electricity and Magnetism. Vol. I, page 177–178.

Digitized by Google

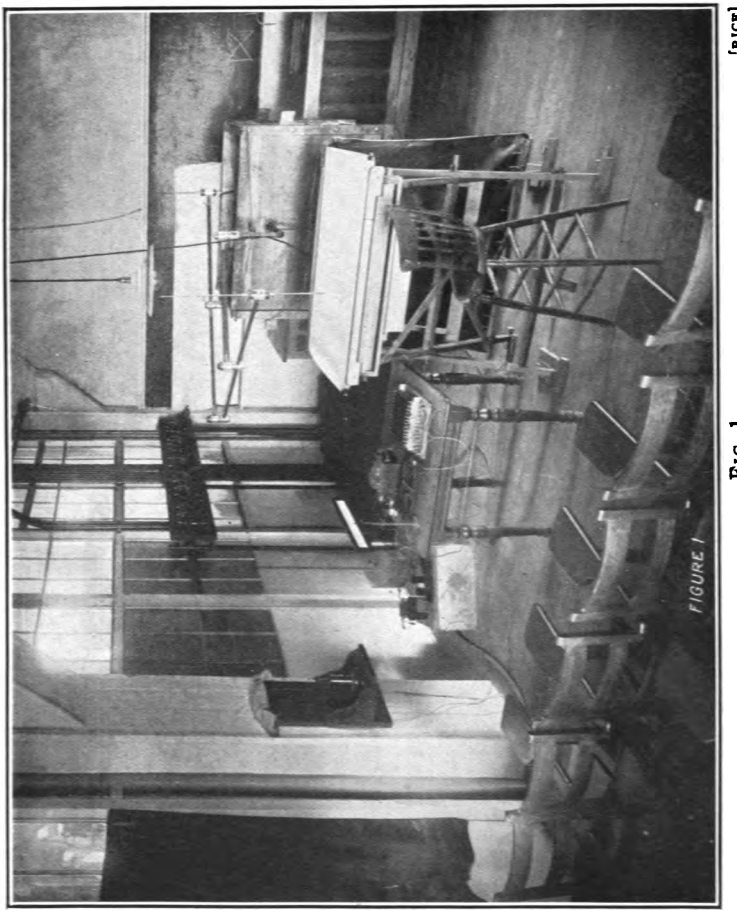


FIG. 1 [RICE]

Digitized by Google

Digitized by Google

The desired diagrams can be obtained in a variety of ways[5] some of which are enumerated below:

I. Directly calculated by the process of cut and try. This method is outlined by Karapetoff[6] from which I quote in part; "In order to calculate the permittance (capacity) of a given dielectric, or to find the flux densities and stresses in different parts of it, proceed as follows: The field is mapped out into small cells by lines of force and equipotential surfaces, drawing them to the best of ones judgment, the total permittance is calculated by properly combining the permittances of the cells in series and in parallel. Then the assumed directions are somewhat modified, the permittance is calculated again, and so on, until by successive trials the positions of the lines of force are found with which the permittance becomes a maximum." The method of successive approximations was systematized and used by Lord Rayleigh.[7]

While theoretically possible in all cases this method is very laborious even for problems in two dimensions and for three-dimensional problems it becomes still more exasperating, as will be readily discovered by anyone who tries it. A considerable assistance in the application of this method is rendered by experimentally obtaining the approximate direction of the lines of force by the well known method of using mica filings, or better fine needle shaped pieces of glass which can be obtained by grinding up glass wool or fabric.

II. Obtain experimentally the isothermal surfaces in the related heat-flow problem. Experimental difficulties such as radiation and conduction, obviously make this method impractical.

III. Obtain the equipotential surfaces in the equivalent electrical conduction problem[8] or what I have termed the electrodynamic method.

5. For references to the numerous articles on this subject I will refer the reader to those contained in the excellent article on this same subject by John F. H. Douglas, A. I. E. E., TRANS. 1915, Vol. XXXIV, Part I, page 1067, "The Reluctance of Some Irregular Magnetic Fields."

6. Electric Circuit, pages 160–163.

7. See Phil. Trans. Royal Society, 1871, p. 77, "On the Theory of Resonance," also "Theory of Sound," Vol. II, p. 171.

8. I understand from Mr. Douglas' paper "The Reluctance of Some Irregular Magnetic Fields", A. I. E. E., TRANS., 1915, Vol. XXXIV, Part I, p. 1081, that Kirchoff first proposed such a method in 1845, and was subsequently modified and employed by many investigators. Re-

Digitized by Google

The possibilities of this method appeared very attractive and it was, therefore, selected as the one best suited for the present purposes.

The Electrodynamic Method

The method consists in obtaining the equipotential surfaces for any desired shape of electrodes from the exactly analogous conduction problem in an electrolyte. Thus the chosen electrode shapes are placed in an electrolyte and alternating current passed between them. The equipotential surfaces are then obtained by an exploring point connected through a quadrant electrometer to a definite known potential with regards to that between the electrodes. The locus of the points of zero potential difference as thus read by the electrometer constitutes the desired equipotential surface.

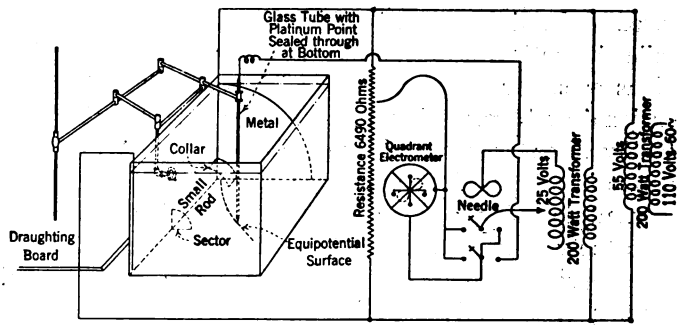


FIG. 2

The electrodes under investigation were placed in a large box made of paraffine treated wood and filled with an electrolyte—ordinary city water being found most convenient. The box was bolted together on the outside as will be seen in Fig. 1, thus eliminating all metal from contact with the electrolyte in the box. A small transformer (200 watt) was employed to step down the 110-volt, 60-cycle lighting circuit to 55 volts which was used as supply for the tests. A non-inductive resistance of 6490 ohms, divided into 50 equal parts, was shunted across the mains between the electrodes. The exploring pointer which was carried by the pantograph consisted of a slender glass tube

cently C. L. Fortescue and S. W. Farnsworth, A. I. E. E., TRANS., 1913, Vol. XXXII, Part I, p. 893, "Air as an Insulator when in the Presence of Insulating Bodies of Higher Specific Inductive Capacity", as well as Mr. J. F. H. Douglas have employed this method,

Digitized by Google

with a small platinum wire sealed through at the end. The glass tube was slipped over a metal tube carried by the pantograph and the insulated wire brought out from the platinum point through the metal tube. The metal tube was used for mechanical stiffening and the glass tube with platinum point so as to avoid electrical leakage. Any defect in the insulation such as a crack in the glass tube being easily detected.

The pointer was connected to one pair of quadrants of the electrometer, the other pair being connected to a point of known potential on the resistance R, Fig. 2. The needle of the electrometer had a metallic suspension and was kept at a definite potential above that of the quadrants by the transformer as shown in the illustration. This method of excitation gives a constant sensitivity regardless of the point at which connection is made to the resistance R. It also makes it possible to change the sensitivity of the instrument by varying the potential applied to the needle. For example, in exploring the field between a given pair of electrodes we can apply a certain low potential to the needle when exploring the dense part of the field, and when exploring the weak part of the field we can raise the potential applied to the needle by selecting a tap on the exciting transformer. Thus, we can maintain equal accuracy in all portions of the field.

Some of the advantages of using the arrangement described above are as follows: The use of alternating current eliminates polarization, to a large extent, and automatically gives "reversed" readings. The use of a quadrant electrometer has the advantage that it takes practically no energy to operate, and it is a good zero instrument since when a point has been nearly located the difference in potential between the quadrants is small in comparison with that of the needle and under these conditions the deflection is very nearly proportional to the potential difference being measured.[9]

The fact that these experiments were carried out on a large scale combined with the small energy necessary to operate the electrometer made it possible to use ordinary city water as the electrolyte which is obviously a great convenience.

9. For the theory of the quadrant electrometer reference may be made to Maxwell, "Electricity and Magnetism," Vol. I, page 338; Jeans, "Electricity and Magnetism," Vol. I, page 108; J. J. Thomson, "Electricity and Magnetism, Vol. I, p. 97–103.

Digitized by Google

Method of Procedure

In applying the electrodynamic method to problems having symmetry about an axis of revolution, a quadrant or octant of the actual figure was studied because in this manner the size of the electrodes used could be made larger and, therefore, the accuracy correspondingly improved. Skeleton electrodes were used because of the obvious ease with which they can be cut out of tin or other metal, and for the further reason that if it ever becomes possible to obtain a mathematical solution of such problems the boundary conditions would be of as simple geometry as possible. Of course in applying the resulting diagrams to the design of any piece of apparatus the electrode shape which would actually be built and used would conform to one of the experimentally obtained equipotential surfaces at some distance

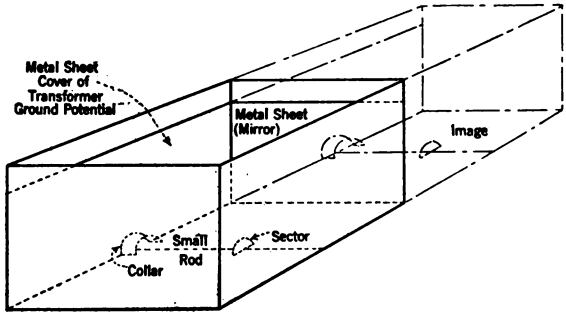


FIG. 3

from the actual skeleton electrodes. Under some circumstances it would be desirable to employ actual models of the desired electrodes.

The method of images is obviously applicable and is of considerable value in improving the accuracy and simplifying many problems. For example, if we wish to study the disturbing influence of one bushing in proximity to another, when they are at opposite potentials, we can set up the experiment as shown in Fig. 3. In this manner we can determine the maximum stress between the two bushings and the minimum stress on the outside of the bushing. Of course a diagram taken in this manner is no longer a plane section through a figure of rotation.

Theoretically there is no difficulty in obtaining the solution of electrostatic problems involving materials of different inductive capacities by this method, as we may employ electrolytes or

Digitized by Google

materials having the proper relative conductances. Practically, however, there are obvious difficulties in obtaining materials having suitable characteristics especially for the case of three-dimensional problems.

In Fig. 4A is illustrated the use of a high-resistance substance such as carbon or a silicon clay composition, etc., as high inductive capacity material immersed in a suitable electrolyte to represent the surrounding air or low inductive capacity material.

Another method is to use an insulating diaphram to separate two electrolytes of different conductivities one inside and the

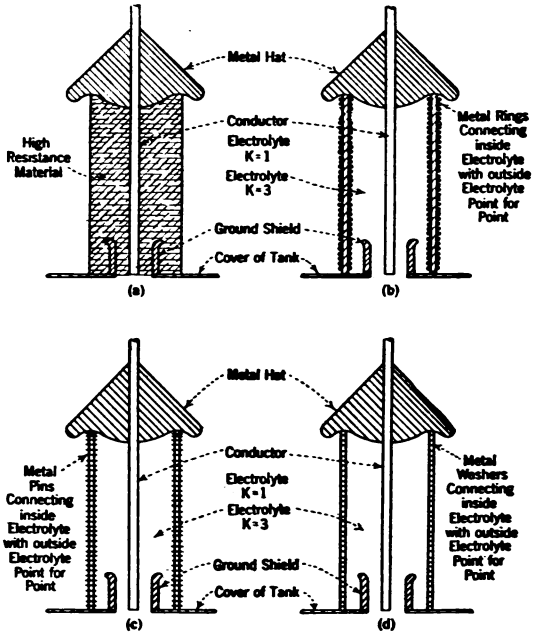


FIG. 4

other outside of the shell. In Fig. 4B a series of wire rings are used which are connected together metallically. In Fig. 4C, the same method is shown except that metal pins are substituted to connect the outside with the inside point for point. Still another and possibly the simplest method of carrying out the same principle is shown in Fig. 4D and was suggseted to me by Mr. G. B. Shanklin. It consists in building up the separating shell of alternate metallic and insulating washers. It will be observed that the methods employing the wire rings or washers are only applicable to problems having circular symmetry.

Digitized by Google

It is difficult in all of these methods to obtain the equipotential surfaces inside of the containing shell, although this can be accomplished in some instances. For example, in the case of a bushing, by placing the quarter section inverted at the top of the large wooden box somewhat as shown in Fig. 5, the exploring plane would then be at the surface of the electrolyte.

It will be seen that in this simple apparatus we have a most remarkable calculating machine which is able to obtain the solution of Laplace's equation and automatically calculate and plot the results for boundary conditions which as yet have not been obtained by analytical methods. The accuracy merely depends upon the scale and care with which the experiments are carried out. For example, in the experiments here described the potential of any point on the full sized diagram, 3 ft. by 4 ft. (90 cm. by 120 cm.) could be determined inside of a pin head. Of course, the diagrams are not accurate to this extent due to the fact that the electrodes used were large compared with the size of the containing box, and, therefore, the edges of the diagrams show large distortions, as will be readily seen by comparing the experimental diagram Fig. 9 with the mathematical solution for the similar case Fig. 10. The first two diagrams are also subject to slight pantograph errors arising from a lack of rigidity and accuracy of the original pantograph. The later diagrams are more accurate as a new pantograph was constructed of large thin walled steel tubing and provided with ball bearings throughout.

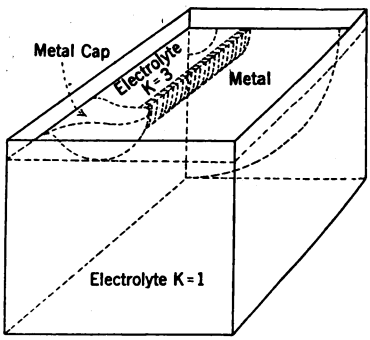


FIG. 5

Before taking a diagram the inside of the paraffine treated wooden box was painted over with a mixture of beeswax and rosin to eliminate or reduce to a minimum any conductivity of the wood.

Completing the Diagrams.

After obtaining an experimental diagram giving the equipotential surfaces for equal or unit differences of potential, in the manner described above, the diagram may be completed by drawing in the family of orthogonal surfaces which divide the field into unit tubes of electrostatic flux. Besides being a great

Digitized by Google

help to the eye in using the diagrams this process furnishes a graphical check on the accuracy of the experimental work. If it is found possible to draw in an orthogonal family of surfaces so that the elementary condensers, cut out between the equipotential surfaces and tubes of electrostatic flux, have the same capacity throughout the field, we know that our diagram is the one and only solution of that particular electrostatic problem. For it is known that there is one and only one solution of any problem in electrostatics. In the second place, the following two conditions must be fulfilled when the field is mapped out in unit tubes of electrostatic flux, and in equipotential surfaces for every unit difference of potential.

I.—The tubes of flux must intersect the lines of force everywhere in the field at right angles, for if this were not true there would be a component of the potential gradient (or electric intensity) along an equipotential surface which is impossible in a static field.

II.—The unit cells, or elementary condensers, which are cut out by the intersection of unit tubes of flux (or force) and unit equipotential surfaces must have the same capacity everywhere in the field. The correctness of this condition can be seen by the following reasoning.

All the elementary condensers between two adjacent flux lines, that is, cut out by a unit tube of flux, are in series and if they were not of equal capacity they would not divide the potential difference equally between them. This is contrary to the assumption that the field is to be divided up into equipotential surfaces for every unit difference of potential.

Again we see that the elementary condensers between any two adjacent equipotential surfaces are in parallel and have unit impressed electromotive force across them. Therefore, if they were not of equal capacity they would not divide the flux equally between them ($\varphi = C e$), which would be contrary to the condition that the field is to be divided into equal tubes of flux.

The process of drawing in the lines of force was briefly as follows: An appropriate height for the unit cell was selected near the axis of symmetry of the diagram, a perpendicular [10] was

10. A convenient method of erecting the perpendiculars is to employ a small plane mirror held, for example by a block of wood at right angles to the drawing board. When the part of the equipotential line which is seen in the mirror forms a continuous smooth curve with the part of the equipotential line which is viewed directly, perpendicularity exists and a line can be drawn using the mirror as a straight edge.

Digitized by Google

erected from this point on the equipotential surface half way to the next one. The perpendicular was then drawn to the next equipotential surface which cut the first perpendicular half way between the two equipotential surfaces. The latter perpendicular was extended half way to the next equipotential surface and the process continued,—in this follow your nose fashion,—until an entire flux line was completed. A smooth curve was then drawn through the intersection of the perpendiculars. After completing a pair of lines in this manner the mean heights of the elementary condensers or unit cells were calculated assuming a constant value of capacity. These mean heights were then plotted on the diagram and it was inspected to see whether the flux line, obtained by perpendiculars, was a good mean curve through all these points. At the beginning of a diagram these points were generally high and low in an erratic manner as would be expected. Another flux line was then obtained by the method of perpendiculars, the smooth curve drawn through the intersection and the mean heights calculated as before and compared with the drawn in curve. In this manner the flux lines were built up one upon another. After completing six or seven flux lines it was generally found that the calculated heights of the cells were showing a slight consistent deviation from the curve as obtained by perpendiculars in some part of the field. The constant error was then distributed throughout all of the flux lines so as to make the two criterions, namely, perpendicularity and equal capacities, come into as harmonious agreement as possible. The work of drawing in more flux lines was then continued and the various processes repeated until the entire diagram was completed.

The fact that it was possible to satisfactorily complete the above process is considered a good check on the accuracy of the experimental work.

Determination of Capacities from the Diagrams

After completing the diagrams by dividing up the field into elementary cells, we can calculate the capacity of any desired part of the field by properly combining the elementary cylindrical condensers in series and in parallel. For example, in the diagram, Fig. 12, we may desire to calculate the capacity assuming a single dielectric between equipotential surfaces 0 to 36 and bounded by flux lines 0 to 54. Here we have 54 of our elementary condensers in parallel and 36 in series. Now since

Digitized by Google

the small cylindrical condensers are all of the same capacity C_u we can write as the total capacity of the part of the circuit under consideration

$$C = \frac{54}{36} C_u$$

or,

$$C = \frac{m}{n} C_u$$

where m = number of elementary cells in parallel.
n = number of elementary cells in series.
C_u = the capacity of the unit cell or the capacity of the elementary cylindrical condenser assumed for the particular diagram.

C_u will obviously depend upon the assumed inductive capacity and size of the diagram.

In selecting the mean height of the first cell which determines the capacity of the unit cells no particular value was chosen, the spacing for the flux lines being selected only for convenience in construction. They are not therefore, strictly speaking, unit cells.

It is obviously necessary to assume some limit to the extent of the field in making any calculation on a field of this type for, if we assumed the central rod with cap infinite in extent as well as an infinite plane with hole and collar, the capacity of the entire circuit would be infinite.

A check on the accuracy of the capacity as calculated from any of the diagrams could be obtained from a measurement of the resistance of the circuit as set up in the large box combined with a determination of the specific resistance of the electrolyte used. I am sorry that I neglected to accurately record this data when taking the various diagrams.

In the case of the diagram of Fig. 28, the following resistance measurements were retained.

Artificial Equipotential Surfaces

Voltage applied, 60-cycle	54.2	volts.
Current	1.39	amperes.
Resistance	39.0	ohms.

Artificial Equipotential Surfaces Removed

Voltage applied, 60-cycle	54.2	volts
Current	1.30	amperes.
Resistance	41.7	ohms.

Digitized by Google

The resistivity of the electrolyte used (Schenectady city water) was determined from a sample taken from the box during the experiment and was found to be approximately 3000 ohm-cm. at 25 deg. cent.

A comparison of the measured resistance of the circuit with and without artificial equipotential surfaces shows that by their introduction we have lowered the resistance of the circuit or, if considering the capacity, we have increased the capacity by the addition of artificial equipotential surfaces.

It will be readily seen that in those cases where we are merely interested in determining the resistance to flow for any of the problems which obey the Fourier-Ohm law, such as the flow of an ideal incompressible fluid, heat, or the so-called electrostatic and magnetic fluxes and current, we merely have to set up the desired electrodes in an electrolyte of known specific resistance and make a determination of resistance. The model used in the tests need not be the same size as the actual piece of apparatus which it is desired to study but may be either a magnified or reduced image. If the linear dimensions are all n times as large as the original then the conductance will be n times larger than it would be for the original model and inversely. A simple and also general method of obtaining the relation between the resistance in ohms as determined from the conduction experiments and the electrostatic capacity of the equivalent electrostatic problem is to compare the two cases for parallel plane electrodes at close spacing when neglecting all edge effect.

The well known expression for the capacity of a parallel plate condenser expressed in practical units is

$$C = \frac{A}{4\pi d} \; k \frac{1}{9 \times 10^{11}} \text{ farads}$$

and the resistance between the same electrodes is

$$R = \frac{d}{A} \rho \text{ ohms}$$

where A = area of the dielectric or electrolyte, or what is the same thing, the area of one plane.
d = spacing between the planes.
k = specific inductance capacity (permittivity) of the dielectric.
ρ = specific resistance (resistivity) of the electrolyte in ohms cm.[3]

Digitized by Google

If we now substitute the value of $\frac{A}{d}$ in terms of R and ρ in the above equation for the capacity we obtain

$$C = \frac{k\rho}{4\pi R} \quad \frac{1}{9 \times 10^{11}} \text{ farads.}$$

as the expression giving the capacity of our electrodes in terms of the resistance measurements[11] R and ρ.

As an illustration, we may calculate the capacity of a bushing built from the diagram of Fig. 28 full size, assuming permittivity unity. The resistance measurement of a quadrant of the bushing gave approximately 40 ohms, and therefore, the resistance for the complete structure would be 10 ohms. Assuming ρ = 3,000 ohm-cm., we have

$$C = \frac{\rho}{4\pi R} \quad \frac{1}{9 \times 10^5} \text{ microfarads}$$

$$= \frac{3000}{4\pi \times 10} \quad \frac{1}{9 \times 10^5} = 0.000027 \text{ microfarad}$$

Study of Electrode Shapes

The following are some of the questions which presented themselves at the outset, and which it was hoped could be answered by taking various diagrams of the electrostatic field by the electrodynamic method:

I. What is the best form of equipotential surface for the rod or high-potential electrode?

II. What is the best form of surface to select for the cover of the tank with a hole in it?

III. Is there a proper best ratio of rod to hole diameter under various conditions?

IV. Are hats desirable? Of how great an assistance are they in screening the bushing from surrounding influence? Are they useful in acting as a rain shed and thereby reducing the field distortion under rain conditions, etc.?

V. Can artificial equipotential surfaces be of material assist-

11. See A. E. Kennelly, *Electrical World*, December 29, 1906, Vol. XLVIII, page 1239, who has used this method for determining the capacity of wireless antenna.

Digitized by Google

ance in bringing about a better distribution of stress in the solid or supporting dielectric; and, at the same time, what are their effects upon the distribution of stress in the air and under oil part of the dielectric? Are their effects conflicting?

Application of the Electrostatic-Field Diagrams to Bushing Design

The problem of high-voltage bushing design is in reality a problem involving two or more dielectrics of different inductive capacities. Therefore, in general the diagrams obtained by using a single electrolyte only offer approximate solutions of our problem.

There are two conditions, however, in which the introduction of high inductive capacity material does not result in a distortion of the field by flux refraction.

Case I. High inductive capacity material in parallel with the air dielectric, that is, when the supporting dielectric conforms to a line of flow. In this case the form and distribution of the flux and equipotential surfaces are neither altered in form nor distribution—nothing is changed under these conditions when considering perfect dielectrics.

Case II. High inductive capacity material in series with the air dielectric, that is, when the additional material conforms to an equipotential surface. In this case the form of the equipotential and flux surfaces is not distorted by refraction. There is, however, an increase in the total amount of flux at constant applied potential difference which causes a change in the distribution of the stresses. The stress in the part of the field where the high inductive capacity (permittivity) material has been inserted is reduced, and that in the low capacity (permittivity) material increased. Therefore, in this case allowance has to be made for this effect.

In the above cases it is not necessary to have the surface of discontinuity rigorously conform to the flux or the equipotential surface since a small variation will not greatly disturb the field. This can be easily seen by making simple calculations by the law of flux refraction, which states that the tangent of the angle of incidence θ_1 is to the tangent of the angle of refraction θ_2 as permittivity of the first medium k_1 is to the permittivity of the second k_2.[12]

12. For example see Jeans, "Electricity and Magnetism," p. 335; Webster, "Electricity and Magnetism," p. 327; Karapetoff, "The Electric Circuit," p. 28 or 163.

Digitized by Google

Thus

$$\frac{\tan \theta_1}{\tan \theta_2} = \frac{k_1}{k_2} \qquad \text{(See Fig. 6)}$$

As an example consider the case in which

$k_1 = 1$ (air)
$k_2 = 3$ (oil)
$\theta_1 = 70$ deg. (the assumed angle of incidence)

Then,

$$\tan \theta_2 = \tan \theta_1 \frac{k_2}{k_1}$$

$$\tan \theta_2 = 2.747 \times 3 = 8.25$$

$\theta_2 = 83$ deg. (the angle of refraction)

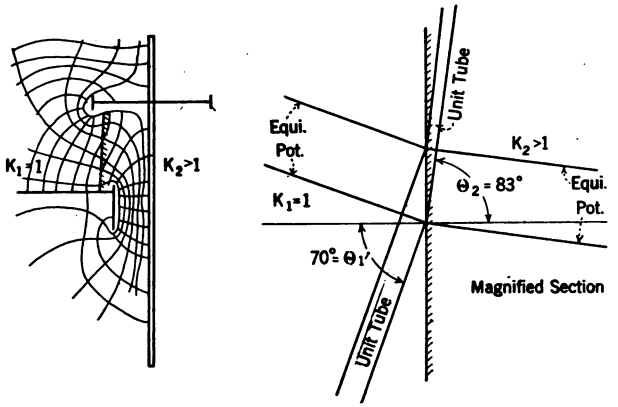


FIG. 6

As θ_1 approaches 90 deg., that is coincidence with the line of force, θ_2 also approaches 90 deg., and in the limit we have the case of two dielectrics of different permittivities in parallel. Under these conditions the form of the electrostatic field is unaltered by the presence of the two dissimilar materials, and the flux density in the air is not increased thereby. If θ_1 approaches zero degree then, in the limit, we have the case of two dissimilar dielectrics in series, and for this case the flux density in the two materials is the same, but due to the increase in total amount of flux the density in the air is increased by the presence of the higher permittivity material.

The above considerations show that there are two cases in which we can apply the diagrams obtained by using a single electrolyte to bushing design without fear of large errors being intro-

Digitized by Google

duced due to flux refraction between the dissimilar materials which are in practice necessarily used for bushing.

Uniform Field Type of Bushing

Thus applying Case I we see that it may be possible to so shape the electrode that the *strongest surface of discontinuity* between the supporting or high inductive capacity material and the air conforms closely to a line of flux. In that case the introduction of the solid material will not alter the field distribution and we would thus obtain one of the infinite number of theoretically correct designs. If this design can be obtained without making the electrodes of an impractical shape or size, this particular solution of the problem would be all that we require. For the case of ideal or perfect dielectrics, which assumes that the surface of discontinuity between the air and solid dielectric does not introduce a weakening influence, *the strongest surface would be an equigradient surface which coincides with a line of flux.*[13]

In this type of bushing it will be observed that the surface of discontinuity receives the full value of the potential gradient and therefore any weakening influence due to the surface of discontinuity between dissimilar dielectrics will exert its maximum ill effect. In the following a bushing built along these lines has been referred to as the "High-Air-Efficiency Bushing." It may also be called the "Uniform-Field Type," since the supporting dielectric and air are in parallel in an essentially uniform field.

By the use of artificial equipotential surfaces placed so as to bring about uniform gradient in the supporting dielectric, this type of bushing would, assuming perfect dielectrics, be as small as it is possible to construct, that is, it would use the air and any available supporting dielectric to their maximum efficiencies.

Radial Field Type of Bushing

If we apply Case II to bushing design we would obtain a condition in which the potential gradient is zero along the surface of discontinuity between the air and supporting dielectric, and, therefore, has its full value normal to the surface. A bushing of this type would not be affected by surface conditions. It is

13. It may be of interest to compare this suggested criterion which assumes ideal dielectrics with that suggested by C. L. Fortescue and S. W. Farnsworth, and J. M. Weed's discussion, A. I. E. E., TRANS., 1913, Vol. XXII, Part I, p. 893, "Air as an Insulator when in the Presence of Insulating Bodies of Higher Specific Inductive Capacity."

Digitized by Google

obviously impossible to have the supporting dielectric connecting the grounded and high-potential electrodes actually coincide with an equipotential surface since the two electrodes must be at different potentials, nevertheless the condition can be approximately obtained in practise. This type of bushing has been referred to as the radial-field type. In this case the supporting

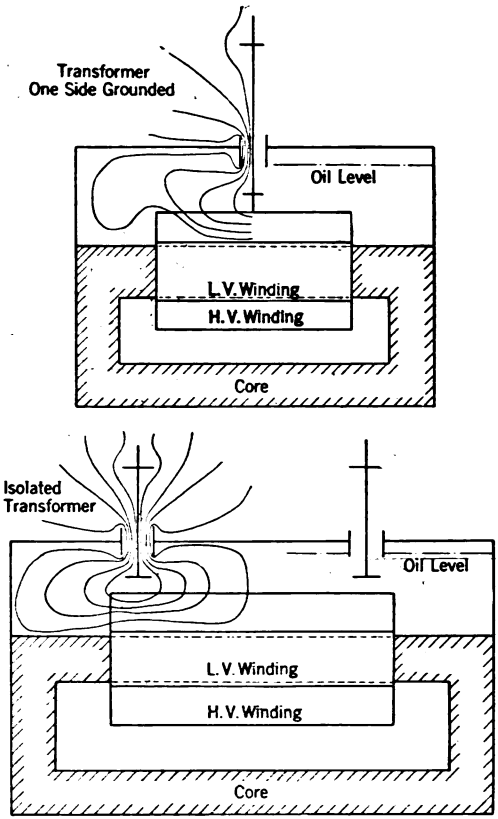


FIG. 7

and air dielectrics are essentially in series in a radial field. If the *surface effect* is very great, that is, if the component of the potential gradient along the surface has to be very small, this type of bushing when provided with artificial equipotential surfaces to obtain uniform stress in the supporting dielectric would result in as small a bushing as it is possible to construct. In this case the potential gradient would be approximately

Digitized by Google

normal to the surface and is, of course, only limited by the strength of air.

Under-Oil End. In the above discussion we have considered the top part of the bushing where two greatly dissimilar dielectrics must generally be employed. The under oil end of the bushing can, as a fair approximation, be treated as a single dielectric problem since the dielectrics usually employed do not differ very greatly in inductive capacities.

The under-oil end requires careful study due to the proximity of disturbing influences such as the core and windings of the transformer. It may be found desirable to use a rather large cap on the under-oil end to shield the bushing from these disturbing influences.

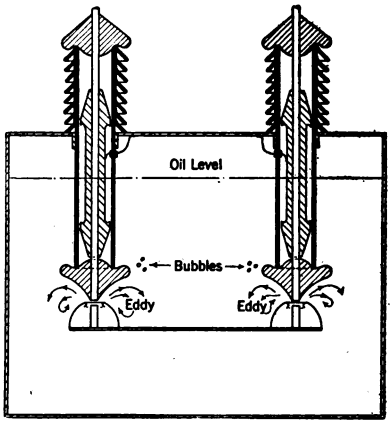


FIG. 8

This part of the problem will have to be carefully considered in conjunction with the whole design of the transformer or switch, etc. Fig. 7 is an illustrative suggestion of transformer design which would assist in an efficient under-oil-bushing design. Fig. 8 shows a switch design in which a large cap is used to reduce the tendency for an arc to re-strike, and, at the same time, provides a sort of deflector which throws the gas bubbles, etc., away from the surface of the dielectric. This could be given a sort of curved or bucket shape so as to produce eddies which might reduce the height of oil necessary over the contacts, etc.

Explanation of Diagrams

The diagrams are drawn for equal tubes of electrostatic flux or force and equal differences of potential between equipotentials.

Digitized by Google

That is, they are plane sections through the solid figure of revolution. Thus, if we imagine this plane section rotated about the axis of symmetry, the lines in the diagrams will cut out the correct surfaces—the equipotential lines and flux lines will generate equal tubes of flux and equipotential surfaces for equal differences of potential. The elementary cells, or elementary cylindrical condensers, thus cut out will have the same capacity throughout the field.

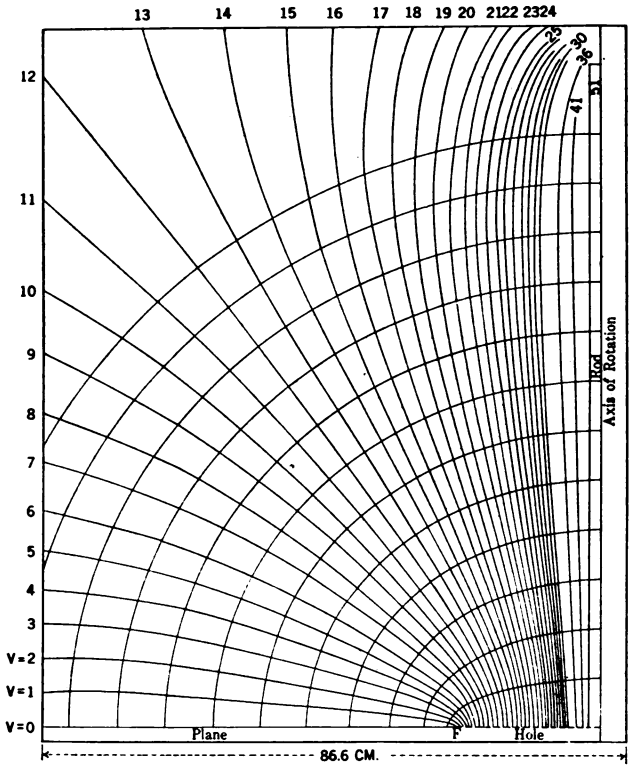


FIG. 9

In the case of diagrams, Figs. 27 and 28 dealing with the use of artificial equipotential surfaces the tubes of flux were not drawn in since they would be discontinuous at the metal surfaces. For this reason it was thought that they would confuse rather than add to the diagrams.

Discussion of Diagrams

Fig. 9. (*Mathematical Solution Fig.* 10). It will be readily seen that if we assume our transformer or switch tank sufficiently

Digitized by Google

large, we can consider the top of the tank as an infinite plane with a circular hole in the middle. As our desired means of metallic connection the simplest would be merely a wire passing perpendicularly through the hole in the tank connecting the inside with the outside. As these electrodes constitute the simplest imaginable form from which to design a bushing their electrostatic field was the first studied.

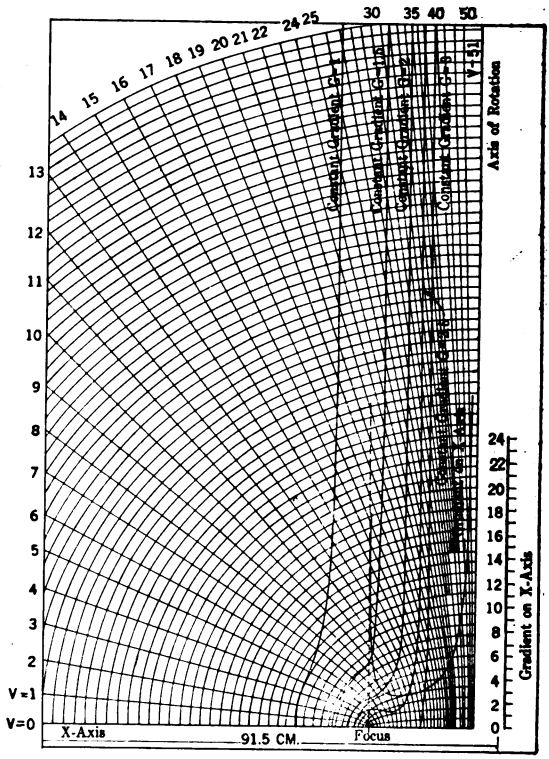


FIG. 10

This diagram shows the characteristics of what has for convenience been termed the radial-field type.

In designing a bushing from this diagram we would probably select equipotential surface 1 or 2 to represent the cover of the tank with hole and rounded edge which makes the stress on the supporting dielectric about three times as high as allowable for the air part of the dielectric. In order to stress the supporting dielectric near the rod to approximately the same value as that at the edge of the hole we would select as our rod an equipotential

Digitized by Google

surface somewhere between No. 25 and No. 30. Under these conditions the ratio of rod diameter to hole diameter would be about 5 to 1. There are, however, many factors (such as the relative strengths of the dielectrics employed and whether the strength is equal in all directions, etc.) which will influence the above ratio and it should, therefore, not be considered as a fixed quantity.

The edge of the hole in the tank must clearly be embedded in the supporting, stronger than air, dielectric to eliminate over stressed air near the edge. That is, the value of a ground shield is clearly shown. This type of bushing will necessarily be quite high in order not to over stress the air at the top.

A study of this diagram suggested that a mathematical solution of this case should be quite easily obtained, due to the apparent simplicity of the equipotential surfaces and their mutual resemblance. Some of the lines of force were drawn in and were seen to conform fairly closely to confocal ellipses, having the edge of the plane as focus (see Fig. 9). This suggested that if there were no disturbing influences, that is, if the rod were very small in diameter and infinitely long and the plane also infinite in extent, the solution of the problem would consist in a confocal system of hyperboloids of one sheet as the equipotential surfaces, and confocal oblate spheroids as the surfaces of force. A plane section through the axis of symmetry of this figure is then a family of confocal hyperbolas and ellipses. The minor axis of the ellipses is the axis of symmetry or the axis about which the plane figure is rotated in order to cut out the solid figure.

In order to test this assumed solution of the problem, a diagram was constructed as follows:

Two large confocal ellipses were constructed having the minor axis along the rod and the radius of the hole in the plane as semi-major axis. The space between these two ellipses was then divided up into cells (see Fig. 11) which obeyed the required geometrical law:

$$\frac{2\pi r \times h}{d} = C \text{ (a constant)}$$

where r = the mean radius of the cell
h = distance between the two confocal ellipses
d = the other dimension of the small rectangular cell (or the distance between the concentric cylinders).

Digitized by Google

By cut and try, the space between the two ellipses was divided up into small cells of constant C. This value, C, is proportional to the capacity of the small concentric cylinder condensers which would be cut out by rotation around the minor axis. The family of hyperbolas which has the same focus as the ellipses was then drawn through the cells. The figure was then completed by drawing in the complete family of con-

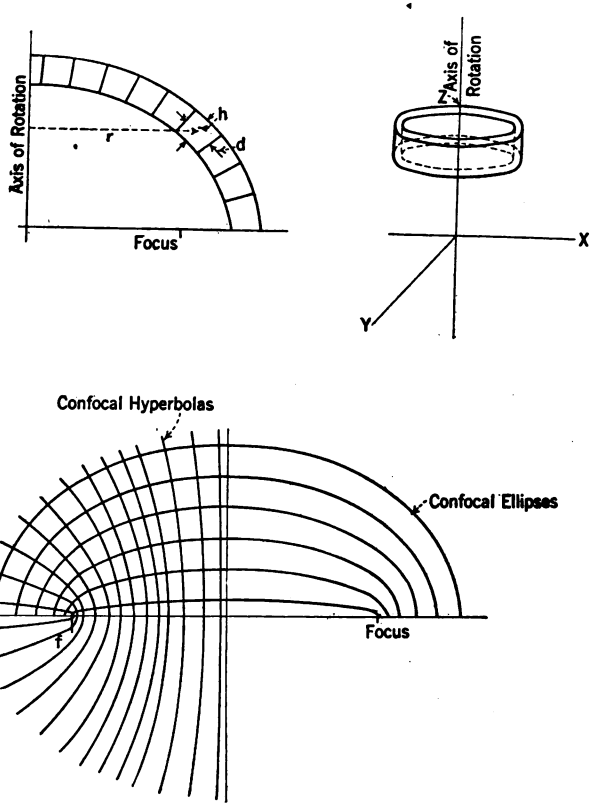


FIG. 11

focal ellipses which divided the whole field into cells having the same capacity or constant C. The fact that it was possible to complete this construction is a graphical proof of the correctness of the assumed solution; namely, that confocal hyperboloids of one sheet are the equipotential surfaces, and confocal oblate spheroids the boundary surfaces of the tubes of flux.

After obtaining the solution of the problem by this method,

Digitized by Google

I found that it was well known; for example Maxwell[14] discusses the mathematical solution of this and similar problems. Other treatments will also be found in many books.[15]

Notwithstanding the numerous treatments of the subject it was not until a lengthy study of these sources, besides correspondence and later the great privilege of an interview with Professor W. E. Byerly, that I was able to obtain what appeared to me to be a clear and useful solution of the problem.

I believe that there are other engineers who find it difficult to readily understand, and therefore use, to the best advantage, the results of the great deal of extremely valuable mathematical work which is available in the various treatises. It seems to me a great pity that the mathematicians do not more frequently reduce their results to a readily utilizable form, and wherever possible sketch out, with examples, some of the applications which must occur to them while working on the subject. In spite of the drudgery which necessarily accompanies any numerical calculations, I believe that a writer would be amply repaid for his trouble by the greatly increased number of people who would study and be able to use his results.

Another difficulty, which I have frequently encountered, is the fact that the writer assumes too great a familiarity with existing mathematical works on the part of his readers. No one is better able to supply page references to what he considers a good and clear treatment of his statements "it has been proved". I also believe that no work would suffer from the inclusion of an appendix of "it can be easily shown" and in some cases the "hences". All of these additions could be skipped by the fluent mathematical readers but would be available as wonderful time savers and often life savers to the ordinary engineer. For these reasons I have included an unexpurgated edition of two electrostatic problems in the appendix to this paper.

Problem I. The distribution of the electrostatic field when any two confocal hyperboloids of revolution of one sheet, and of the same family, are maintained at given potentials.

14. See Maxwell, Electricity and Magnetism, Vol. I, p. 235 and following.

15. See Byerly, Fourier Series and Spherical Harmonics, p. 238–247. J. H. Jeans, Electricity and Magnetism, p. 238–244; A. G. Webster, Electricity and Magnetism, p. 203–242, 273, etc.; I. Todhunter, The Functions of Laplace, Lamé and Bessel, Chapter XXI p. 211.

Digitized by Google

This problem is useful as an approximation in studying high-voltage bushing design; it also gives us an interesting variety of possible electrode shapes for use in testing insulating materials, where it is desirable to be able to calculate the gradients. When testing a dielectric of given inductive capacity immersed in a dielectric having a different inductive capacity (*i.e.*, hard rubber

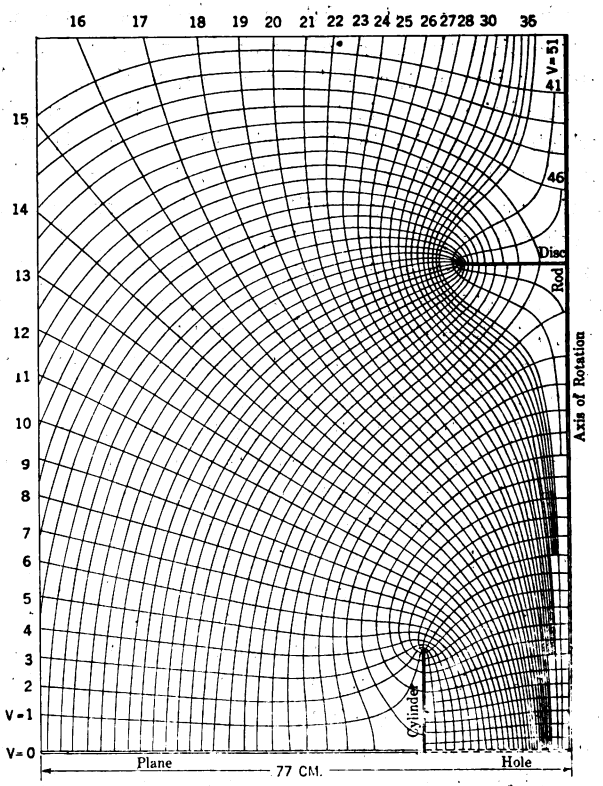


FIG. 12

in air or oil) the edge effect can be eliminated by shaping the test piece so as to follow a line of force or flux.

Problem II. The distribution of the electrostatic field when any two confocal hyperboloids of revolution of two sheets and of the same family are maintained at given potentials. This problem is of interest as an approximation to a group of problems which are of frequent occurrence in engineering. For example, it may be applied to switch electrodes at various spacings; also,

Digitized by Google

as an approximation in vacuum tube designs, such as X-ray tubes, kenotrons, etc. That is, it is an approximation to the problems of two elongated electrodes at various spacings, (*i.e.*, two needles or a needle and a plane) etc.

Fig. 12. This diagram[16] shows a form of field intermediate between the radial and uniform-field types. The effect produced by adding a collar to the edge of the hole in the plane is shown. The addition of a collar or extended ground shield is generally used on the air end to shield the bolts necessary in clamping

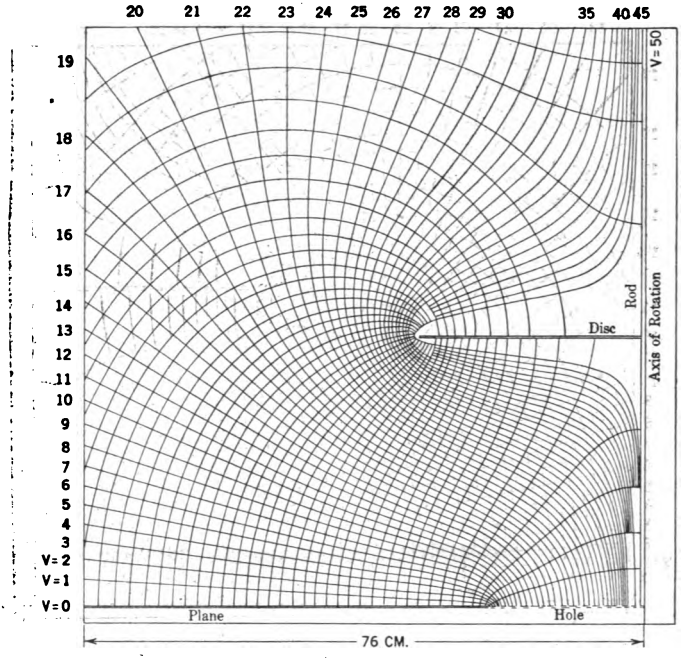


FIG. 13

the bushing to the tank. It may also be used to shield switch mechanism, etc. A ground shield extending below the surface of the oil on the under-oil end is usually necessary in order to remove the stress on the air above the oil.

In designing a bushing from this diagram, we would probably select equipotential surface No. 2 or No. 3 as cover of the tank with hole and collar or ground shield and an equipotential surface

16. Dr. C. P. Steinmetz has published this diagram in the fourth edition of his Electrical Engineering, page 116, which has recently appeared.

Digitized by Google

resembling No. 20 as high potential electrode. In practise we would probably not build the electrode of the shape of surface No. 20, but would make up the electrode of a straight rod and cap which would be roughly equivalent to surface No. 20. The addition of the cap and collar does not greatly alter the conclusions regarding the ratio of rod to hole diameters as outlined above when discussing this point for the simplest case, that of a rod passing through a hole in a plane. That is, the edge effect of the collar or cylinder is about the same as that for the edge of a plane.

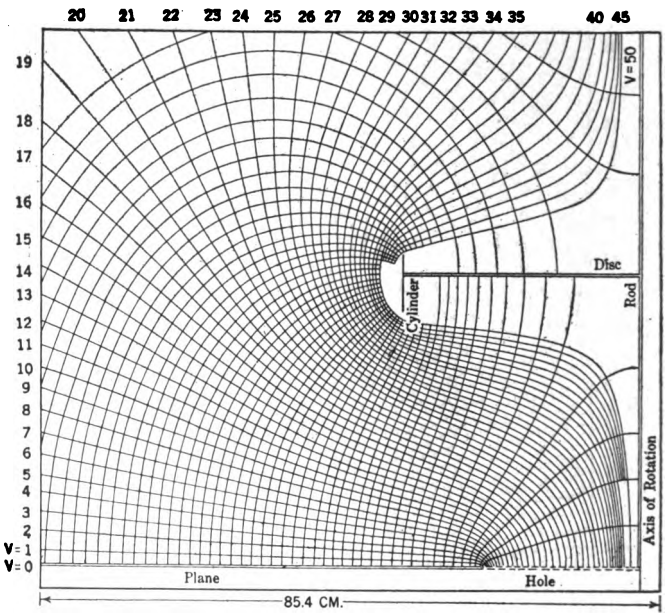


FIG. 14

Fig. 13, 14 *and* 15. These diagrams are essentially of the uniform-field type. A study of diagrams, Figs. 9 and 12, indicated, that by increasing the size of the cap and bringing it closer to the case, the efficiency of the use of the air part of the dielectric could be increased. That is, it appeared practical to shape the electrodes of the bushing in such a way that the distribution of the electrostatic field would approach the condition in which the strongest surface assuming ideal dielectric (constant gradient or flux density) coincides with a line of force in the part of the field where it is desired to introduce the dielectric of higher specific

Digitized by Google

inductive capacity than the rest, which may be air or oil. As previously stated the resulting bushing would use the air at its maximum efficiency and hence the resulting bushing would be as efficient, with respect to the air path, as any of the infinite other solutions which could be obtained by using flux refraction combined with various electrode configurations.

In order to experimentally test out this conclusion, Figs. 13, 14 and 15 were taken. Skeleton electrodes were used, as

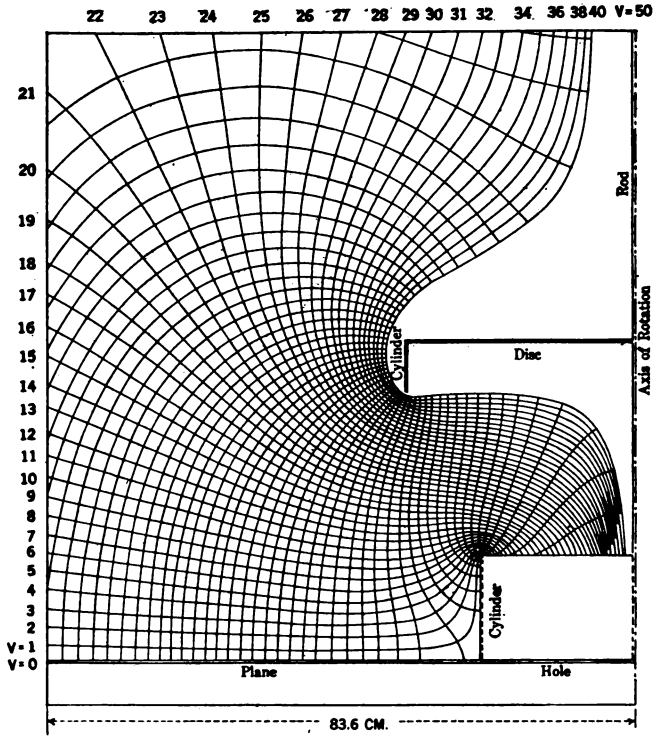


FIG. 15

in the previous experimental work, in order to simplify matters. For instance, one electrode may consist in a thin piece of sheet iron, or tin, with a hole in it; the other electrode a small wire with an attached metal disk. The proper actual shape of the rod with cap and the tank will then be selected from the equipotential surfaces which are obtained by the experiment.

For the new diagrams the size of the cap was increased so as to have a diameter of about 1½ times that of the hole in the

Digitized by Google

plane, and was placed at about one diameter from the plane. The short cylinder was added to the sheet-iron disk for Fig. 14, to form a skeleton electrode which would flatten out the equipotential surfaces near the edge of the disk, and also to bring the lines of force into a more nearly cylindrical form. Briefly, to give the effect of a cap having a greater radius of curvature at its edge.

In applying these diagrams to bushing design we would probably select the equipotential surface 2 as the top of the tank, and an equipotential surface between 28 to 32 as our rod with cap. This selection gives approximately equal gradient at the edge of the hole in the tank and at the rod. Also, the maximum gradient on the cap is not too different from that near the tank. The supporting insulation, stronger than air and of higher specific inductive capacity, would probably be put in somewhere between flux lines number 4 to 7.

It is apparent from the diagram that this bushing would have its maximum air stress near the edge of the cap, and therefore, would probably arc-over clear of the solid insulation, unless the surface introduces appreciable weakening influences. This matter will have to be settled by experiment and then given consideration according to its magnitude. Assuming a surface which does not appreciably affect the arc-over of the bushing, we obtain from the full size diagram, Fig. 14, the following result. Selecting equipotential surface No. 30 as our rod with cap, we see that the maximum potential gradient in the air occurs near the edge of the cap. We must, therefore, select this gradient to be that at which air breaks down or approximately 21 kv. effective per cm. The distance between equipotential surfaces 30 and 29 is about 0.6 cm. (on the full size diagram).

Hence

$$\frac{e\Big|_{30}^{29}}{0.6} = 21 \text{ kv. effective per cm. (assumed strength of air.)}$$

$$e\Big|_{30}^{29} = 12.6 \text{ kv. effective, the potential at which breakdown will occur between these two surfaces.}$$

Digitized by Google

Between the cap and the tank (equipotential surface No. 2) there are 28 equipotential surfaces drawn for equal differences of potential. Therefore, the arc-over voltage of this terminal would be obtained by multiplying the number of equipotential surfaces between that selected as the rod with cap and the tank, by the voltage which would cause breakdown if applied between the two consecutive surfaces in the densest part of the air field. In this case the number of surfaces is 28, and the voltage at which breakdown first occurs between two surfaces is 12.6 kv. effective.

Hence

$$28 \times 12.6 = 350 \text{ kv. effective arc-over voltage.}$$

The operating voltage, assuming a safety factor of 3, would be 116 kv. effective. This calculation assumes that as soon as the gradient at the edge of the cap reaches the breakdown value, arc-over will occur (unstable condition).

With regards to the stresses on the solid or liquid dielectric which is used in this design, it may be of interest to observe that the maximum gradient, which occurs along the path between rod and edge of tank, is approximately 63 kv. effective per cm. or three times that at which air breaks down.

The efficiency with which this bushing uses the air part of the dielectric may be estimated as follows:

Assuming arc-over to occur from the point of maximum stress on the cap, that is, near the outer edge, to the tank a distance of approximately 30 cm., we see that this air path under uniform gradient, should arc-over at

$$30 \times 21 = 630 \text{ kv. effective.}$$

Hence, taking the efficiency to be the ratio of the arc-over voltage as estimated above from the diagram, to this uniform gradient condition, we have

$$\text{Efficiency} = \frac{350 \text{ kv.}}{630 \text{ kv.}} = 55 \text{ per cent.}$$

Fig. 15, shows the effect of the addition of a collar or cylindrical ground shield to a bushing of this type. The conclusions are similar to those which may be drawn from the previous diagrams.

Digitized by Google

Tests on Experimental High-Air-Efficiency Bushing

An experimental bushing was constructed from a photographic reduction of Fig. 14, as outlined in Fig. 16. Two supporting dielectrics were tried. In the first case a smooth porcelain piece conforming as closely as possible to the flux line No. 7 was used. In the second case the porcelain surface was corrugated as shown in the figure between flux lines No. 4 and No. 7.

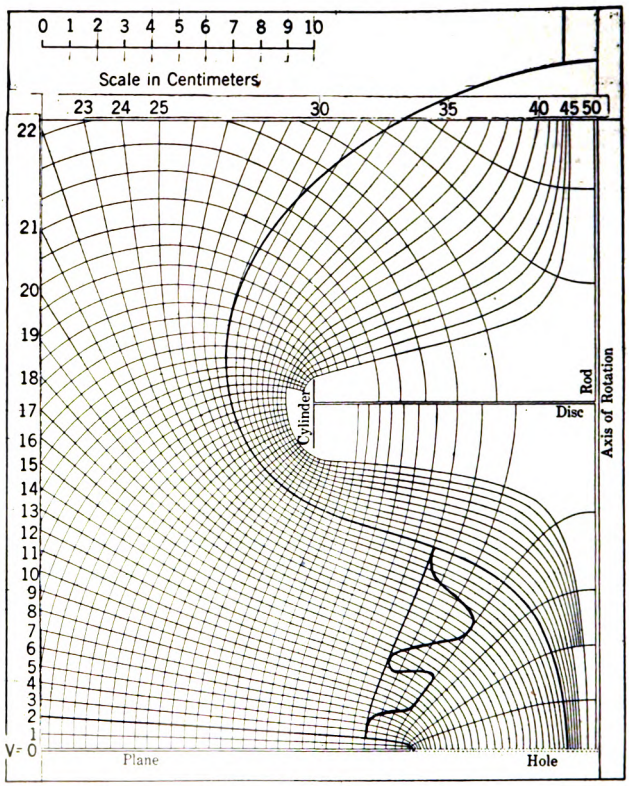


Fig. 16

The electrodes and porcelain pieces were cemented together with a sort of sealing wax compound, considerable effort being made to make good joints at the electrodes. Equipotential surface No. 30 was chosen as the central electrode shape but was modified at the top as shown in the figure as it was not thought important to conform to the diagram at the top part of the electrode where the stress on the air is very low. Equipotential surface

Digitized by Google

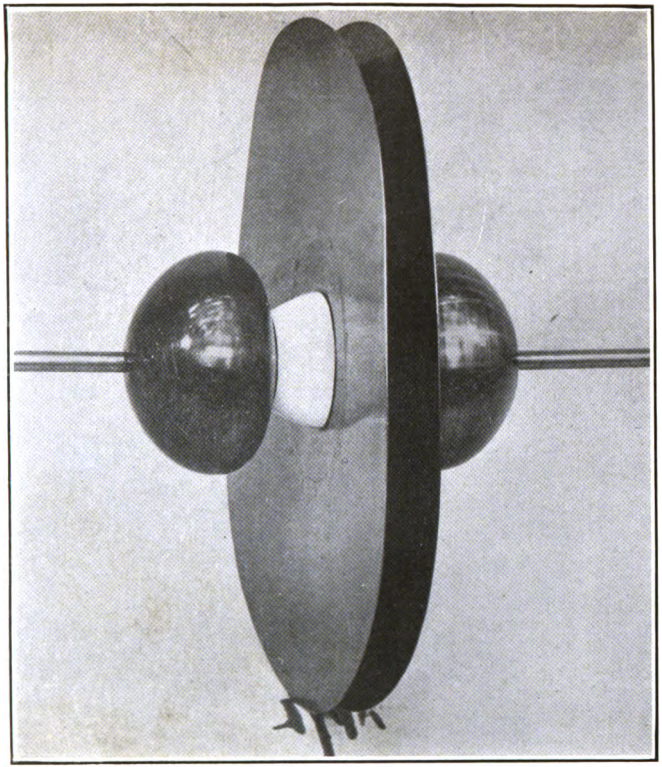


FIG. 17

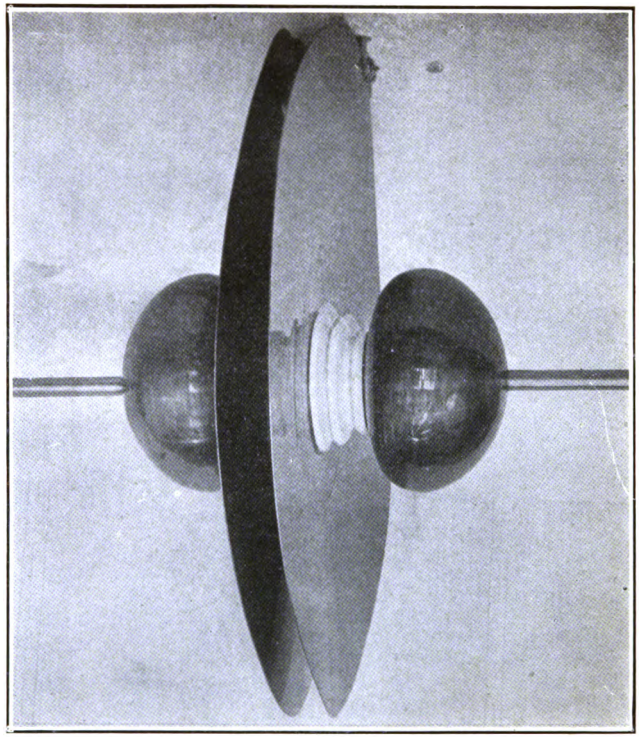


FIG. 18

Digitized by Google

Tests on Experimental High-Air-Efficiency Bushing

An experimental bushing was constructed from a photographic reduction of Fig. 14, as outlined in Fig. 16. Two supporting dielectrics were tried. In the first case a smooth porcelain piece conforming as closely as possible to the flux line No. 7 was used. In the second case the porcelain surface was corrugated as shown in the figure between flux lines No. 4 and No. 7.

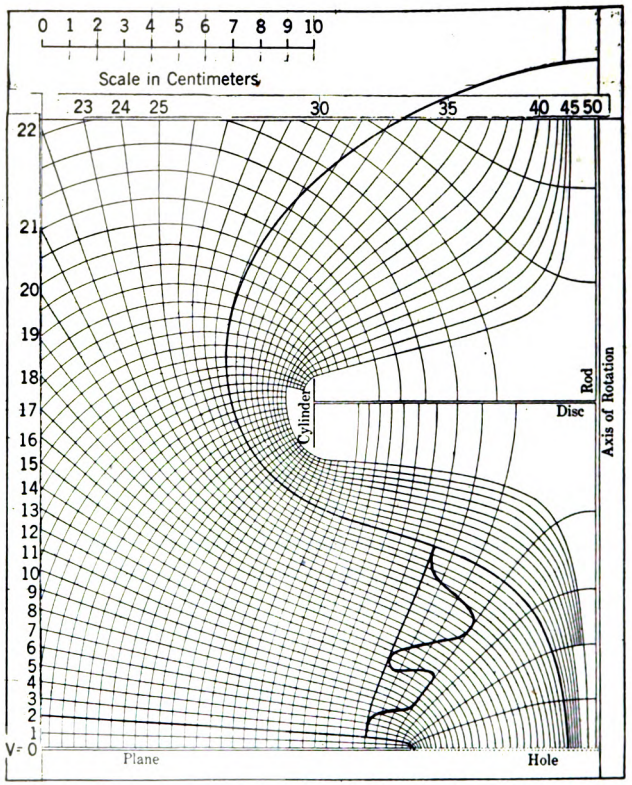


Fig. 16

The electrodes and porcelain pieces were cemented together with a sort of sealing wax compound, considerable effort being made to make good joints at the electrodes. Equipotential surface No. 30 was chosen as the central electrode shape but was modified at the top as shown in the figure as it was not thought important to conform to the diagram at the top part of the electrode where the stress on the air is very low. Equipotential surface

Digitized by Google

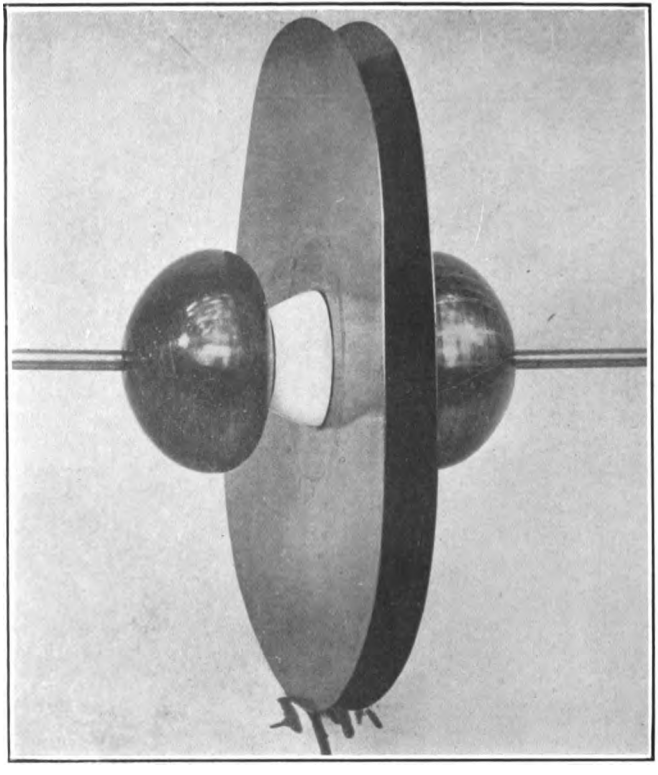


FIG. 17

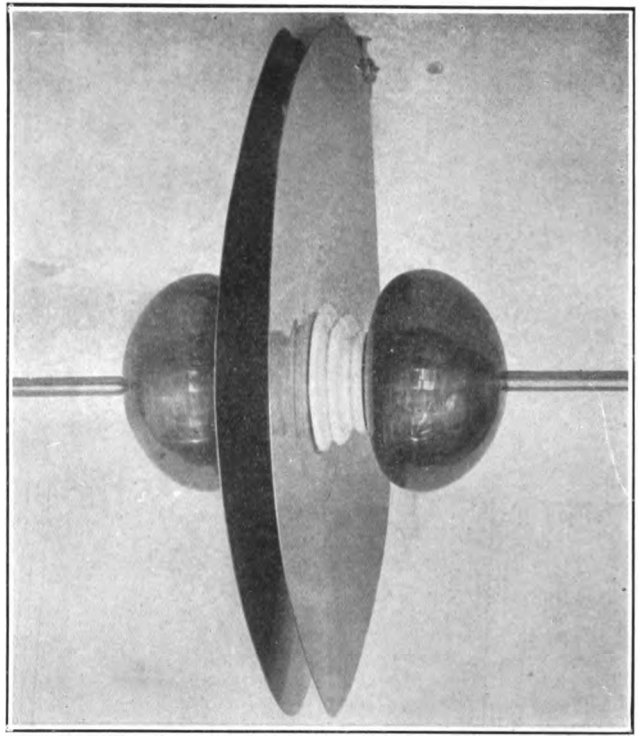


FIG. 18

Digitized by Google

Digitized by Google

No. 2 was selected as the ground plane and extended 43 cm. from the axis. The upper and lower parts of the bushing were made as nearly alike as possible; Fig. 17 and 18 show the general appearance and construction of the bushings.

The principal electrical characteristics, as obtained from the experimental diagram, Fig. 14, are as follows: The maximum gradient on the air part of the dielectric occurs on the cap of the central electrodes and well away from the surface of the supporting dielectric. The gradient at this point reaches 21 kv. effective per cm. (or the assumed breakdown strength of air) at about 117 kv. effective. The gradient along flux line No. 7 (7.3 cm. long) is practically uniform and will reach 21 kv. effective per cm. at about 153 kv. The gradient at the edge of the ground electrode and the central rod are approximately equal and are about three times the maximum gradient on the air.

The arc-over voltages of the corrugated and smooth bushings may be estimated as follows:

(1) *Smooth Surface*

If we assume that the surface and joints of the porcelain do not introduce disturbing influences, arc-over should occur clear of the surface at 117 kv. effective. For this potential difference the gradient along the surface of the porcelain would be 16 kv. effective per cm.

(2) *Corrugated Surface.*

If we neglect refraction effects and make the very rough assumption that the corrugations introduce half air and half porcelain in series in a uniform field we would have for the arc-over voltage

$$e = G_1 \left(x_1 + \frac{x_2}{k} \right) \text{ arc-over voltage}$$

Where

$$G_1 = 21 \text{ kv. per cm.}$$

$$x_1 = x_2 = \frac{7.3}{2} \text{ cm.}$$

$$k = 5 \text{ porcelain}$$

Hence,

$$e = 21 \left(3.65 + \frac{3.65}{5} \right)$$

$$e = 92 \text{ kv. effective.}$$

Digitized by Google

and arc-over would occur by unstable corona formation in the corrugations at 92 kv. effective.

At this voltage the average potential gradient along the arc-over path would be $\frac{92}{7.3} = 12.6$ kv. effective per cm.

Summary of Tests

Sixty-Cycle Arc-over Voltage. (average of ten readings)

Surfaces cleaned with absolute alcohol and wiped dry

I Smooth Surface.....80 kv. ± 10 kv.
Average gradient.....11 kv. per cm.

II Corrugated Surface.....72 kv. ± 10 kv.
Average gradient.....9.9 kv. per cm.

Surfaces cleaned as above and then covered with an oil film.

I Smooth Surface.....75 kv. ± 10 kv.
Average gradient.....10.3 kv. per cm.

II Corrugated Surface.....82 kv. ± 5 kv.
Average gradient.....11.2 kv. per cm.

The arc-over voltages after visible carbonization points have been formed at the sealing wax joints and on the porcelain is given below. This condition is reached after about 15 arc-overs, when dry clean surfaces are used and in 5 to 10 arc-overs when the surface is oiled. Handling the surface results in about the same arc-over voltages.

I Smooth Surface.....50 kv. ± 2 kv.
Average gradient..... 6.85 kv. per cm.

II. Corrugated Surface..... 5 kv. ± 2 kv.
Average gradient..... 7.25 kv. per cm.

Surface of electrodes and porcelain covered with city water, that is, the surfaces were sprayed after all the oil had been removed.

I Smooth Surface.....23 kv. ± 3 kv.
Average gradient..... 3.15 kv. per cm.

II Corrugated Surface.....27 kv. ± 3 kv.
Average gradient..... 3.7 kv. per cm.

Surface oiled and a needle point ¼ in. long placed upright at the corrugated surface on the ground plate.

First arc-over.....50 kv.
Average gradient..... 6.85 kv. per cm.

Digitized by Google

After about three arc-overs a carbonized point could be seen to form at the arcing point on the upper electrode above the needle, also considerable carbonization took place around the needle.

Under these conditions the arc-over

was.....35 kv.
An average gradient of..... 4.8 kv. per cm.

60 *Cycle Under-Oil Tests.* After the above mentioned tests were completed the bushing was immersed in oil (40 kv. oil as measured by standard gap of 0.2 in. (0.5 cm.) between 0.5 in. (1.27 cm.) terminals) in order to determine the under-oil characteristics.

In both cases arc-over took place over the porcelain surfaces and in the corrugated bushing followed in and out of the corrugations. The results were

I Smooth Surface.....122 kv.
Average gradient..... 16.7 kv. per cm.
II Corrugated Surface.....144 kv.
Average gradient..... 19.7 kv. per cm.

Impulse Arc-over Tests. Impulse tests were made using F. W. Peek's impulse generator.[17] Impulses having various frequencies and wave shapes were used but as the results were in good agreement in all cases only a typical set of readings will be given. The calculated frequency of the impulse wave is given as 500 kilocycles with a maximum voltage corresponding to 188 kv. effective.

The arc-over voltages as measured by 12.5-cm. spheres placed in parallel with the bushing were as follows:

I	Smooth Surface.....	111.5 spheres only 117. half and half 121. bushing only
	Average gradient.....	16. kv. per cm.
II	Corrugated Surface.....	104. spheres only 111. half and half 117. bushing only
	Average gradient.....	15.2 kv. per cm.

The results were practically identical with clean dry or oiled surfaces.

17. "The Effect of Transient Voltages on Dielectrics." A. I. E. E., TRANS., 1915, Vol. XXXIV, Part II, p. 1857.

Digitized by Google

Observations and Discussion

In all of the tests on the smooth bushing the arc-over appeared to follow close to the surface. In the corrugated case arc-over appeared to take place along flux line No. 7, that is, did not follow in and out of the corrugations. (The only exception was in the case mentioned of the under oil arc-over of the corrugated bushing where the path followed the corrugations in and out).

The previous calculations indicated that the smooth porcelain bushing should arc over clear of the surface at about 117 kv. whereas in test it arced-over along the surface at about 80 kv. ± 10 kv. (oily and dry surfaces do not seem to be greatly different) or say approximately 70 per cent of the calculated arc-over voltage. However, this comparison is not a truly correct one since the arc-over occurred at the surface and not at the point of maximum gradient. A better comparison of calculated and observed arc-overs is obtained by comparing the calculated surface arc-over with the actual surface arc-over.

Sixty-Cycle Tests. (A) Averaging the clean and oily surfaces we have

$$\frac{\text{calc. surface arc-over}}{\text{measured surface arc-over}} \cdots\cdots\cdots\cdots = \frac{153}{77} = 2.0$$

(B) Carbonization points formed after a number of arc-overs

$$\frac{\text{calc. surface arc-over}}{\text{measured surface arc-over}} \cdots\cdots\cdots\cdots = \frac{153}{50} = 3.1$$

(C) Surfaces and electrodes sprayed with water.. $= \frac{153}{23} = 6.6$

Impulse Tests. (D) Clean or oily surfaces..... $= \frac{153}{117} = 1.3$

Many explanations may be advanced for the above results; at first I was inclined to account for them in the following manner.

Case A. Here breakdown occurred over the surface of the bushing at approximately one-half the calculated voltage. To account for this we might assume that a conducting corona ring forms prematurely due to an imperfect joint between the porcelain and electrodes, since at the joint a high stress might exist on the air due to the high inductive capacity material being in series with the air at this point. If such a conducting corona ring was formed the maximum stress upon it would be approximately

Digitized by Google

twice that existing in the uniform part of the field. For if we insert a cylindrical conductor in a uniform field the maximum gradient on the cylinder will be twice the gradient of the uniform field in which it is placed or if we have two infinite plane electrodes having hemicylindrical bosses upon them, then for spacings between the planes such that the field between is essentially uniform in the middle the gradient in the vicinity of the cylindrical bosses will be a maximum on the crest of the boss and will be twice the gradient existing in the uniform part of the field.

The solution of this problem is obtained by the method of images; by superimposing a uniform field upon the field of a linear doublet.[18] A complete diagram of the electrostatic field is given by Maxwell in Plate XV at the end of Vol. II of "Electricity and Magnetism."

If we make the further assumption that the corona ring is unstable then we see that arc-over should occur at approximately one-half the calculated arc-over voltage assuming perfect joints and surfaces, which is about the value observed from the tests. It is of course probable that the gradient at the surface of the boss will have to be somewhat above 21 kv. effective per cm. at breakdown, or what is the same thing, the breakdown strength of air (assumed 21 kv. eff. per cm.) must be reached at a finite though small distance from the surface of the boss. This same effect is well known in the case of wires or concentric cylinders, etc., for example, it has been discussed by F. W. Peek, Jr.[19]

Case B. Carbonization points formed after a number of arc-overs. In this case arc-over took place over the surface at about one third the calculated value. A method of approximately explaining this case may be based upon the assumption that a small hemispherical corona boss forms on the surface of the electrodes. The solution of the electrostatic problem of two infinite planes having hemispherical bosses is obtained by superimposing a uniform field upon the field of a spherical doublet. The gradient is a maximum on the crest of the boss and is three times that in the uniform part of the field.[20]

18. See "Electricity and Magnetism". A. G. Webster, p. 202, also p. 88. Notes on Electric Field Distribution. Journal of the Franklin Institute, July, 1913. W. S. Franklin, p. 72–75.

19. A. I. E. E., TRANS., 1911, Vol. XXX, Part III, p. 1889, "The Law of Corona and the Dielectric Strength of Air."

20. J. H. Jeans, "Electricity and Magnetism," p. 188–191; A. G. Webster, "Electricity and Magnetism", p. 371–373; Lord Kelvin Papers on "Electrostatics and Magnetism," p. 492; J. J. Thomson, "Electricity and Magnetism," p. 158–160.

Digitized by Google

Diagrams of the lines of force or flux will be found in the various references given below and a somewhat similar and instructive case is shown in Plate III at the end of Vol. I—Maxwell, "Electricity and Magnetism."

Case C. Water particles on the surface. In this case arc-over occurs at about one-half the needle-gap arc-over at this spacing. This low arc-over under these conditions may be a sort of progressive breakdown between adjacent water particles or distortion of the field by erratic conduction, etc.

Case D. The impulse test shows an arc-over voltage which is very close to the calculated arc-over assuming that it takes place clear of the surface. To the eye, however, the arc-over seems to take place along or very close to the surface and therefore there seems to be some disturbing influence at work which the above explanations do not take into account.

The previous calculations for the corrugated porcelain bushing indicated that the arc-over should take place along the edge of the corrugations due to unstable corona formation in the valleys of the corrugations. The calculation is necessarily only approximate as the flux refraction produced at the corrugations is neglected.

A comparison of the various cases may, however, be of interest.

Sixty-cycle Tests.

Case A. Oily and clean surfaces ratio of calculated to test arc-over..... $\frac{92}{77} = 1.2$

Case B. Carbonization points formed after a number of arc-overs..... $\frac{92}{53} = 1.74$

Case C. Surfaces sprayed with water..... $\frac{92}{27} = 3.4$

Impulse Test

Case D. Clean and Oily Surface..... $\frac{92}{111} = 0.83$

Explanations similar to those offered for the smooth surface might be advanced but cannot be quantitatively applied as the field conditions are not as definitely known.

Under Oil Tests (60 *Cycles*). The under oil arc-over tests also show a lower value than would be expected if we assume perfect joints and ideal dielectrics.

Digitized by Google

The strength of oil at these large spacings (7.3 cm.) is about 33 kv. effective per cm., and therefore the surface arc-over voltage should be $7.3 \times 33 = 240$ kv. effective for the smooth porcelain surface

$$\frac{\text{calculated surface arc-over}}{\text{measured surface arc-over}} = \frac{240}{122} = 2.0$$

It will be observed that the explanation above (corona ring or joint effect) could be applied to these tests and give what would appear to be a satisfactory explanation of the observed discrepancy between calculated surface arc-over voltage and that obtained from the tests. The corrugated porcelain surface could be discussed qualitatively in a similar manner.

ADDITIONAL TESTS ON "HIGH-AIR-EFFICIENCY BUSHINGS.

The object of the following tests was to determine the disturbing influence of the walls and floor of the room or ground upon the arc-over voltage of this type of bushing. The following tests were made using the *corrugated supporting dielectric* as it was still assembled with the electrodes. The previous under-oil tests had damaged the porcelain surface on one side, and therefore, necessitated submerging the injured end under oil. For this purpose, a wooden oil tank was used, the tests being made on the uninjured end. The surface of the porcelain was oiled for all tests.

Summary of Tests

Sixty-Cycle Arc-Over Voltage. (average of ten readings). Corrugated Surface.

(A) Plane grounded
Arc-over voltage..... 67 kv. ± 5 kv. eff.
Average gradient..... 9.2 kv. per cm.

(B) Plane isolated, central electrode grounded
Arc-over voltage..... 67 kv. ± 4 kv.
Average gradient..... 9.2 kv. per cm.

(C) Bushing entirely isolated.
Arc-over voltage..... 80 kv. ± 10 kv.
Average gradient..... 11 kv. per cm.

A comparison of these tests with the previous ones show a reduction of the arc-over voltage for the grounded cases to about 80 per cent of the previous values. The isolated case agrees closely with the previous tests where the plane was grounded.

Digitized by Google

The results might be expected from the following consideration: In the previous tests the bushing was suspended about 10 ft. above the floor of the room, and therefore was not appreciably influenced by the floor and walls, whereas the present tests were made with the bushing about 2 to 3 ft. from the floor of the room. The conditions of the test had to be changed, due to the fact that it was necessary to have the damaged end of the bushing under oil. Under these conditions the proximity of the floor of the room or ground would have a greater effect upon the grounded cases, A and B, than for case C where both plane and central electrode were isolated.

It may be interesting to note, at this point, that the type of electrostatic field, which we are here concerned with, for example, an infinite rod passing through a hole in an infinite plane is essentially different from the case of two spheres at different potentials in space. In our case the rod and the plane both are considered as going to infinity and are at different potentials. Thus, it is evident that the potential at infinity is indeterminate and the electrostatic field distribution merely depends upon the relative potential between the two electrodes. This can be seen analytically from the mathematical solution for this simplest case (see appendix). The case of two spheres in infinite space is quite different. For example, assume them to have equal and opposite potentials, in that case, the equipotential surfaces are approximately spherical at great distances from the spheres and at an infinite distance the equipotential surfaces around each sphere are two infinite spheres made up of the infinite plane which passes midway between them. By reason of symmetry this infinite plane is seen to be at zero potential since it forms the equipotential surface which lies midway between the two spheres and since this plane goes to infinity the potential at infinity is zero.

If we now assume one sphere at zero potential and the other at a positive potential of such a value as to make the relative potential between the two spheres the same as before, the electrostatic field distribution is no longer symmetrical about the plane midway between the spheres, that is, the field has been changed though the relative potential between the spheres is the same. A diagram of the electrostatic field, under these conditions, is shown in Fig. II at the end of Vol. I Electricity and Magnetism, by Clerk Maxwell. In this diagram, Q, is the spherical surface at zero potential and, A, the other sphere at a

Digitized by Google

positive potential. The concentration of the field about, A, will be observed. This is quite a different matter from the effect of floor, walls, etc., of the room. I have taken the liberty of calling attention to this fact because it has puzzled me considerably and may have bothered others also. The above remarks, of course, do not apply to the case of two bushings in proximity, in which case the fields of the two bushings would have to be treated as one.

Conclusions

In general, the results of tests on the above high-air-efficiency bushings were not very encouraging from the point of view of building a satisfactory commercial bushing of this type. However, if the above suggested explanation of the discrepancy between theory and test were found to be correct, that is, if the disturbing influence is due to corona at the joints between the porcelain and electrodes, it should be possible to eliminate it by electrostatic shielding of these joints. This might eliminate all the lowering of arc-over except that due to rain or sprayed surfaces, and, therefore, might give us a useful bushing for indoor use, especially on testing transformers, where the *impulse safety factor* is not important.

Investigation of the Discrepancy Between Calculated and Test Arc-Over Voltage of Experimental High-Air-Efficiency Bushing

Joint Effect

The following tests were carried out in order to obtain an experimental check upon the explanation offered above which was based upon the assumption that a corona ring formed prematurely at the joint between the supporting dielectric and the electrodes.

Large plane electrodes with smoothly rounded edges were spun up of brass of the form shown in Fig. 19. The object of the design was to obtain as nearly as possible, a uniform field between the electrodes without disturbing edge-effects. The sixty-cycle arc-over voltage was then obtained at various spacings, with planes alone, and when provided with small rings, hemispherical bosses and points. The results are given in the form of curves in Fig. 19.

It will be observed from the data given on the planes alone that the field between them is not accurately uniform since the breakdown gradient changes with the spacing and is in general

Digitized by Google

lower than 21 kv. effective per cm. the approximate strength of air at these large spacings. The arc-overs were, however, well distributed and did not show a tendency to take place at the rounded edges. The 200 kilocycle impulses arc-over of the planes is given on the curve, and approximately represents the true strength of air under uniform field conditions, as the edge effect does not seem to greatly lower the impulse arc-over.

To show roughly the effect of hemicylindrical bosses small copper rings $\frac{1}{8}$ in. (0.318 cm.) cross-section were used. Two diameters for the rings were tried first, one-inch (0.254 cm.)

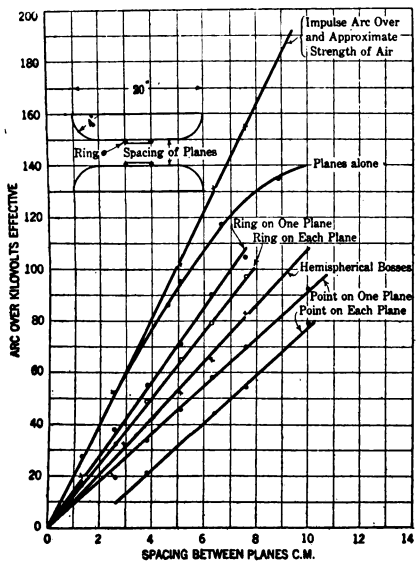


FIG. 19—SIXTY-CYCLE TESTS IN AIR

diameter and secondly, four-inch (10.15 cm.). The results were, however, not appreciably different and, therefore, the averages are shown, first for the case of a single ring on the upper plane, and secondly for a ring on each plane. The rings were not made half-sections because it was not thought necessary for such rough tests. Of course the effect produced by the ring is not rigorously equivalent to a straight hemicylindrical boss except where the cross section of the ring is exceedingly small and the diameter of the ring extremely large in comparison.

The hemispherical bosses used had a radius of $\frac{1}{8}$ in. (0.318 cm.) No appreciable difference was observed between the case in which

Digitized by Google

a boss was placed on one or on both planes, and, therefore, a single curve is shown.

The points or cones which were employed were approximately 30 deg. and $\frac{1}{4}$ in. (0.635 cm.) high and had rather dull points.

From the previous discussion we saw that the apparent arc-over gradient when hemicylindrical bosses were placed upon the planes should be, assuming any corona formation to be unstable somewhat above 10.5 kv. eff. per cm. due to the so-called "energy distance effect" which requires that the surface gradient exceed the breakdown strength of air. The rough tests given above indicate an apparent surface gradient of about 13 kv. eff. per cm. Observation in the dark indicated that arc-over takes place without previously showing corona.

A similar explanation probably suffices to explain the difference between the apparent arc-over gradient, as discussed above, for the case of a hemispherical boss which indicated that on the assumption of unstable corona formation the arc-over would take place at an apparent gradient somewhat above 7 kv. eff. per cm. In test the apparent gradient was found to be about 10 kv. eff. per cm. No corona could be observed in the dark before arc-over.

The case of the small points on the planes is not so easily calculated but is interesting in showing the extreme condition. Observation in the dark showed streamers from the point to the plane just below the arc-over voltage, sometimes resulting in arc-over and sometimes going out, the appearance being like very fine so-called "static sparks" and not a corona like glow.

Surface Effect

Tests in Air and Oil. We have seen that the explanation of the discrepancy between calculated and test arc-over voltages of the high-air-efficiency bushing can be fairly satisfactorily explained on the assumption that the joint between the porcelain and metal of the electrodes was the disturbing influence which brought about the reduction in arc-over voltage. It has also been pointed out that, if this were the true explanation, it should be possible to eliminate the effect by proper electrostatic shielding of the joints. The following preliminary tests were, therefore, carried out in order to roughly check the assumption experimentally.

For this purpose the two brass electrodes used in the previous tests were available, and in addition a second pair of planes were spun up on exactly the same form, except that the annular

Digitized by Google

grooves were added as shown in Fig. 20. The object of the grooves was to supply an electrostatic seal for the edge of the test piece (a glass cylinder in these tests). It is believed that in this manner we have shielded the joint between the test piece and the electrodes, and, therefore, should have eliminated any disturbing influence which might arise from the joints. An imaginary sketch of the electrostatic field about the grooves has been drawn which is also a detail drawing of the groove. Reference may also be made to Figs. XI and XIII, at the back of Vol. I, Electricity and Magnetism, by Clerk Maxwell, which show the screening

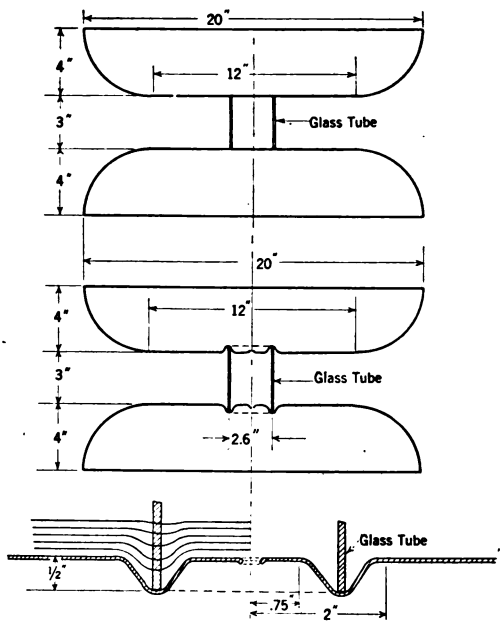


FIG. 20

effect of plates and gratings, which are somewhat analogous cases. Under these conditions the introduction of the glass cylinder of high specific inductive capacity in parallel with the air dielectric should have no effect upon the arc-over voltage, providing the strength of air is not different when in contact with the test piece.

The data obtained using various test pieces between the smooth and grooved planes in air and oil are summarized by the curves, Figs. 21 to 25. During the tests the barometer varied between 74.5—76. cm. Hg.; the temperature between 23 deg. cent. to 27 deg. cent. and humidity between 34 per cent to

Digitized by Google

53 per cent. The effect of these variations did not show themselves above the experimental errors involved in the tests and therefore all the data was averaged together. The glass cyl nders used as test pieces were ordinary soda glass approximately 2.5 inches (6.25 cm.) diameter with a wall thickness of about 0.07 inches (0.18 cm). In all cases minute longitudinal flaws were visible along the grain of the glass. The edges of the cylinders were roughly ground but the process left appreciable irregularities which probably would be sufficient to introduce corona disturbances, if they are appreciable.

Three conditions of the glass surface were investigated: I—

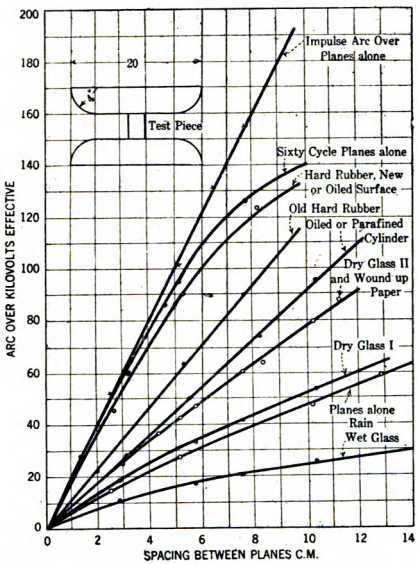

ARC OVER KILOVOLTS EFFECTIVE
SPACING BETWEEN PLANES C.M.
20
Test Piece
Impulse Arc Over Planes alone
Sixty Cycle Planes alone
Hard Rubber, New or Oiled Surface
Old Hard Rubber
Oiled or Parafined Cylinder
Dry Glass II and Wound up Paper
Dry Glass I
Planes alone Rain Wet Glass

FIG. 21—SMOOTH PLANES—SIXTY-CYCLE TESTS IN AIR

Glass cylinders cleaned with absolute alcohol and dried with a cloth. This case is represented on the curves as dry glass (I).

II—Glass cylinders cleaned as in (I) and then heated for about 3 hours at 180 deg. cent. The cylinders were then removed from the oven, handling being done by means of dried fibre strips, and set up between the planes for test. Arc-overs were taken while the cylinders were still hot and also after they had reached room temperature. The later condition is that referred to on the curves as dry glass (II). The hot arc-overs differed from the room temperature ones merely in proportion to the change in air density on the supposition of a heated film of air in the vicinity of the hot cylinders.

Digitized by Google

III—Wet glass cylinders. For these tests the cylinders were held under the water faucet just before tests were made.

For the tests in which the cylinders were coated with paraffine, or oil, etc., the test piece was soaked in the hot material and then tested after reaching room temperature.

The tests with hard rubber varied considerably as shown by the two curves. The upper curve is for hard rubber cylinders which had been re-surfaced with fine emery just before test. The lower curve shows the arc-over after the test piece had stood around the laboratory for a week or so. The tests with oiled

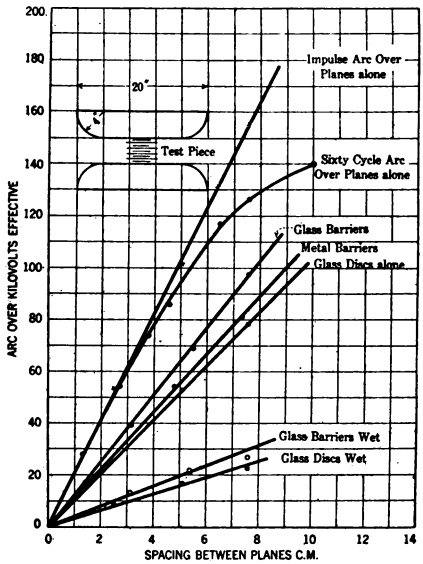


FIG. 22—SMOOTH PLANES—SIXTY-CYCLE TESTS IN AIR

hard rubber refer to cylinders which had been soaked in No. 6 transil oil for a few days.

Tests were also made on wound-up paper cylinders impregnated with compound.

The tests using glass disks given on curve sheet Fig. 22 were intended to show the effect of breaking up the surface first by the natural irregularity of the piled up disks (see Fig. 26), secondly with larger glass disks inserted at intervals, and thirdly with metal disks inserted at intervals. The glass disks were 0.075 in. (0.19 cm.) thick and 2 in. (5 cm.) and 4 in. (10 cm.) diameter and had roughly ground edges. The metal barriers were 5 in. (12.7 cm.) in diameter and 0.019 in. (0.048 cm.) thick.

Digitized by Google

The under oil tests were carried out in a large wooden oil tank containing No. 6 transil oil, testing 40 kv. between 0.5-in. (1.27 cm.) terminals at 0.2 inches (0.51 cm.) spacing.

The impulse tests were made using F. W. Peek's impulse generator [21] with an impulse resembling half a cycle of a 200 kilocycle sine wave. The voltages given are on the assumption that arc-over occurs at the top of the sine wave impulse.

A few tests were made using glass tubes and hard rubber cylinders having different diameters, so as to see whether the arc-over was affected by changes in the surface resistance be-

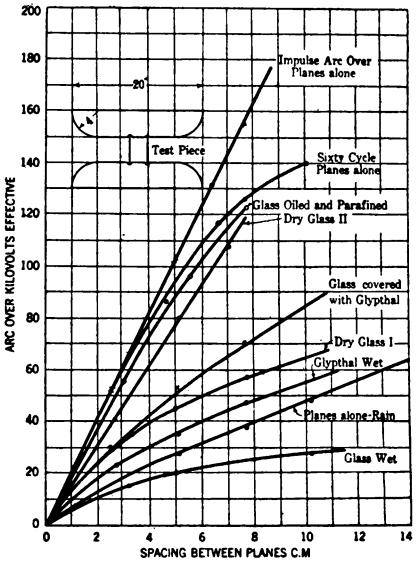


FIG. 23—GROOVED PLANES—SIXTY-CYCLE TESTS IN AIR

tween the planes. The tests did not, however, show any variation from the previous ones.

The incompleteness of the data and the irregularities which occurred between different samples of the same material as well as the rather crude methods of test make any conclusions rather questionable. I am, however, inclined at present to the following conclusions.

If all precautions were taken to absolutely free the test samples from moisture, and furthermore, if practically perfect joints were made between the test samples and the planes, either by electro-

21. See footnote 17.

Digitized by Google

statistically shielding the joints or by mechanical fit, I believe that the presence of insulation in parallel with air or oil, etc., in a uniform field would not result in a breakdown lower than that of the weakest material. When, however, the joint is not carefully made, I believe that premature breakdown occurs at the joint when a high inductive capacity material is placed in parallel with a lower inductive capacity material.

When dealing with dielectrics, which have been cleaned and dried, with what would be considered great care in the household sense of the word, there appears to be a very large reduction in arc-over under the conditions here discussed, namely, under uniform field conditions, depending upon the character of the material which cannot be accounted for by joint effect. In

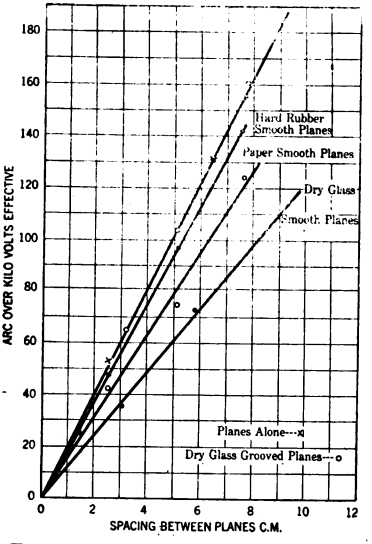


FIG. 24—IMPULSE TESTS IN AIR—200 KILO-CYCLES

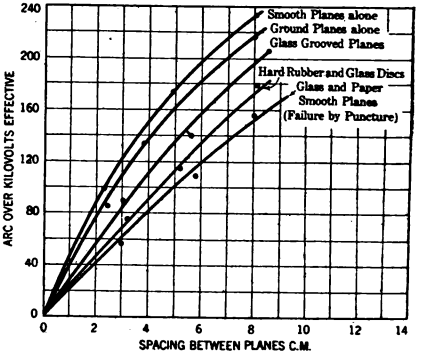


FIG. 25—SIXTY-CYCLE TESTS IN OIL

general, it may be further pointed out that materials such as clean new hard rubber, oiled, or paraffined surfaces, which Mr. Harvey L. Curtis has shown have a high surface resistivity under varying humidity conditions, also show a high breakdown under the test conditions here described. From a purely electrostatic point of view it is, of course, obvious that if the surface conduction took place in a perfectly regular and uniform manner it should not result in any reduction in the arc-over of the test pieces as the equipotential surfaces of conduction would coincide

22. The Volume Resistivity and Surface Resistivity of Insulating Materials—*General Electric Review*, October 1915, p. 996.

Digitized by Google

with electrostatic ones and no distortion or increase in stress would thereby result. If, therefore, the reduction is to be attributed to surface leakage or conduction, this effect must be of an erratic and discontinuous nature.

It would be of considerable theoretical interest to test this conclusion experimentally. For example, I believe that a suitably high resistance and homogeneous metallic film could be obtained on a glass cylinder by subjecting it either to a cathode spray or by volatilization in a high vacuum. Some tests were tried in which ground-glass cylinders were coated with graphite, etc., but without satisfactory results.

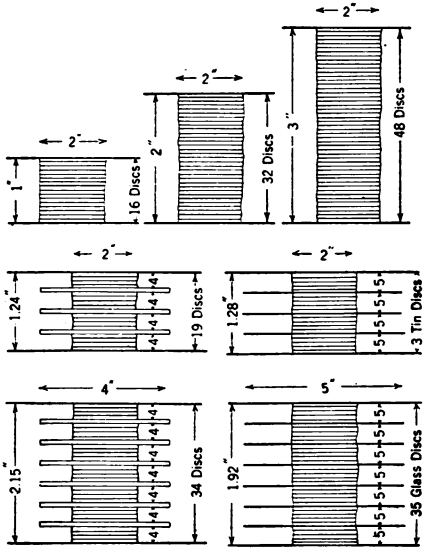


FIG. 26

I believe that a thorough and accurate investigation of this phenomena would be of considerable practical as well as theoretical interest.

REVISED ARC-OVER CALCULATION OF HIGH-AIR-EFFICIENCY BUSHING

A revised calculation of the arc-over voltage of the high-air-efficiency bushing may now be made which takes into account the surface and joint effects. We have seen previously that the surface arc-over of the bushing in air should take place under ideal conditions at about 150 kv. effective. Now, since the

Digitized by Google

electrostatic conditions along the surface are practically identical for the bushing and for the test pieces between the smooth planes, a direct comparison is legitimate except for the fact that a glass surface is probably not identical with a glazed porcelain surface. Nevertheless the comparison is of interest.

Arc-over of High-Air-Efficiency Bushing	Arc-over of Smooth Planes 7.3 cm. Spacing
Tests in Air	
Average of dry and oiled smooth porcelain surfaces	Average of dry and oiled glass
60 cycle, 73 kv. effective	60 cycle, 67 kv. effective
Impulse, 117 kv. effective	Impulse, 90 kv. effective
Surface wet with city water	Surface wet with city water
60 cycle, 23 kv. effective	60 cycle, 21 kv. effective
Tests in Oil.	
Smooth porcelain surface	Glass cylinder,
60 cycle, 122 kv. effective	140 kv. effective

In conclusion it should be observed that if we are forced to use supporting dielectrics, which show large surface effects, we must consider this fact when we form any criterion for the best use of air or oil in combination with the supporting dielectric. If we assume that our surface of discontinuity between the air part of the dielectric and the solid or supporting dielectric, for instance glass, is greatly weaker than air alone, for example—only stands a potential gradient of 7.3 kv. effective per cm. instead of 21 kv. effective as would probably be the case if perfectly dry and clean; then considering this feature alone, we see that in order to use both materials most efficiently, the component of the potential gradient along the surface should not exceed 7.3 kv. effective per cm., whereas the air itself should be used to its full strength of 21 kv. effective per cm. Thus, the component of the potential gradient normal to the surface should be $G = \sqrt{21.^2 - 7.3^2} =$ 19.7 kv. effective per cm. or the flux lines should make an angle of approximately 70 deg. from the surface. This is practically the condition existing in the so-called "Radial Type of Field" in

Digitized by Google

which the supporting dielectric and air are approximately in series in a radial field. It will be seen that when considering ordinary materials from which bushings are usually made that this surface effect practically requires us to go to the radial type of field in constructing a bushing.

CALCULATION OF THE ARC-OVER OF THE TEST PIECE, DESCRIBED AND TESTED BY C. L. FORTESCUE AND S. W. FARNSWORTH.[23]

The electrodes consisted of confocal hyperboloids of revolution of two sheets. The equation of the hyperbolas which constitute the generating curves were obtained from the description and Fig. 20 of the paper as follows:[24]

$$\frac{x^2}{a^2} - \frac{z^2}{c^2} = 1$$

Where

$f = \sqrt{a^2 + c^2} = 1$ in. the semi-focal distance.

and $a = 0.875$ in.

$c = 0.485$ in.

from which we have

$$\frac{x^2}{(0.875)^2} - \frac{z^2}{(0.485)^2} = 1$$

The ellipsoidal hard-rubber supporting dielectric is cut out by rotating the ellipse whose equation was determined in a similar manner to be

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

Where $f = \sqrt{a^2 - b^2} = 1$ in.

and $b = 3.1$ in.

$a = 3.26$ in.

and

$$\frac{x^2}{(3.26)^2} + \frac{y^2}{(3.1)^2} = 1$$

Reference to Fig. 18 or 19 of the appendix shows that the hypobola No. 27 is very approximately the one corresponding to that used for the electrodes. The ellipse bounding the hard rubber is No. 22 counting out from the focal ellipse as 0.

23. See footnote 1.

24. See p. 863 and Figs. 1 and 2 of the appendix.

Digitized by Google

Assuming the breakdown strength of air as 21 kv. effective per cm. and perfect dielectrics corona would start at the junction between the hard rubber and electrodes at 205 kv. eff. If we further assume that the corona formation is unstable arc-over should occur assuming perfect dielectrics without surface or joint effects at about this value. The factor which takes into account the reduction in arc-over, due to what has been called surface and joint effect, for the case of hard rubber in parallel with air in a uniform field, in which the full value of the gradient is along the surface, is applicable in this case. The tests have shown that a factor of about 73 per cent should be applied to the value as calculated neglecting this effect. Thus, the calculated arc-over of this structure is about 150 kv. effective, the test results reported by Fortescue and Farnsworth were given as 160 kv. effective.

Outline of Some of the Possible Methods for Increasing the Efficiency of the Use of the Supporting Dielectric

In the previous discussion on bushing design attention has been principally directed towards studying the possibilities of an efficient use of the air dielectric. Theoretically, the ideal bushing would be that in which the whole dielectric is used to its maximum efficiency, that is, it would be on the point of breakdown simultaneously at all points. Therefore, it is interesting to study the possibilities of increasing the efficiency of the use of the solid or supporting dielectric. For example, inspection of the diagram, Fig. 14 shows that the supporting dielectric in a bushing built along these lines is not used to its maximum strength except right near the rod and edge of the hole in the tank. Therefore, if it is possible by some means to redistribute the stress in the solid dielectric so as to bring about a more uniform condition, it would be possible to greatly reduce the diameter of the bushing as a whole. The following are some of the possible methods which might be employed.

I—Theoretically we could bring about the desired condition provided we had suitable dielectrics of various inductive capacities and dielectric strengths. We could then place the high inductive capacity materials near the rod and edge of the hole in the tank putting the lower inductive capacity materials in the less dense parts of the field and in some such manner as this bring about the condition in which all the dielectrics used were stressed

Digitized by Google

to their maximum strengths. This is the well known principle of graded insulation. Unfortunately there is not a very wide variation in the inductive capacities of the materials which are available in practise.

II—If there were available extremely high resistance materials, or dielectrics, we could construct a bushing which would maintain a proper potential distribution by conduction through the dielectric. This might be called a resistance bushing. A graded resistance bushing would also be possible.

III—Another method is to insert artificial equipotential surfaces and thereby control the stresses in the manner which we desire. In order to effect the desired distribution of stresses the artificial equipotential surfaces must be maintained at the proper potentials. Some of the methods which can theoretically be used for this purpose are as follows:

A. Metallic connection to a proper source of potential. For example, to transformer taps or external balancing resistances, inductances or capacities, etc. A balancing resistance might even be embedded in the dielectric.

B. By conduction through the supporting dielectric. This would be similar to the resistance bushing mentioned above except that the distribution of the conduction current could be modified, in various ways, by the insertion of artificial equipotential surfaces.

C. Electrostatically (or the well known condenser principle)[25] in this case we have the balancing condensers embedded in the supporting dielectric, and, at the same time, forming the artificial equipotential surfaces. Of course graded insulation is also applicable to this type of bushing.

Theoretically where artificial equipotential surfaces are used they could be extended through the surface of the solid or supporting dielectric into the air part of the field where they could be used to assist in bringing about the desired field distribution, and at the same time, even be made to act as petticoats to shield the surface from rain, etc.

Obviously the possibility exists of making various combinations of the above principles.

When the practical difficulties of utilizing the above methods

25. R. Nagel *Elektrische Bahnen und Betriebe*, 1906, p. 278; A. B. Reynders, A. I. E. E., TRANS., 1909, Vol. XXVIII, Part I, p. 209; C. L. Fortescue, *Electrical Journal*, August 1913, p. 718; W. S. Franklin, *Journal of the Franklin Institute*, July 1913.

Digitized by Google

are considered it appears that case III alone, or possibly in combination with grading by inductive capacities, is the most feasible at the present time. Therefore, a brief study of this case was undertaken making use of the electrodynamic method.

Preliminary Study of the Use of Artificial Equipotential Surfaces or Potential Equalizers

Diagrams of Figs. 27 and 28, were taken as a preliminary study of the effects produced by forcing a uniform distribution of

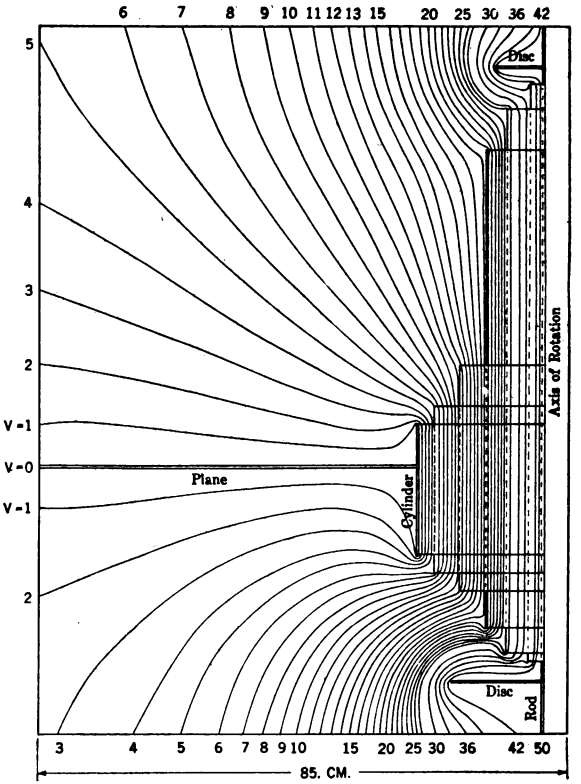


Fig. 27

potential gradient in the solid or supporting dielectric by the use of cylindrical artificial equipotential surfaces. Diagram, Fig. 27, shows the effect when the radial field type is used on the air end and diagram, Fig. 28, for the uniform field type. The under-oil ends are what might be termed semi-radial.

At the outset, it should be noted that it is necessary to study both the air and oil ends simultaneously if they are not symmetri-

Digitized by Google

cal, otherwise the problem is indeterminate. Briefly the method of experiment was as follows: The skeleton electrodes, for Fig. 27 consisted of a plane with cylinder (ground shield) and a central rod provided with a tin disk at both ends. The disk on the under-oil end was put in so as to make a definite field in which to end the artificial equipotential surfaces. If this were not done the bushing would be greatly affected by the piece of apparatus in

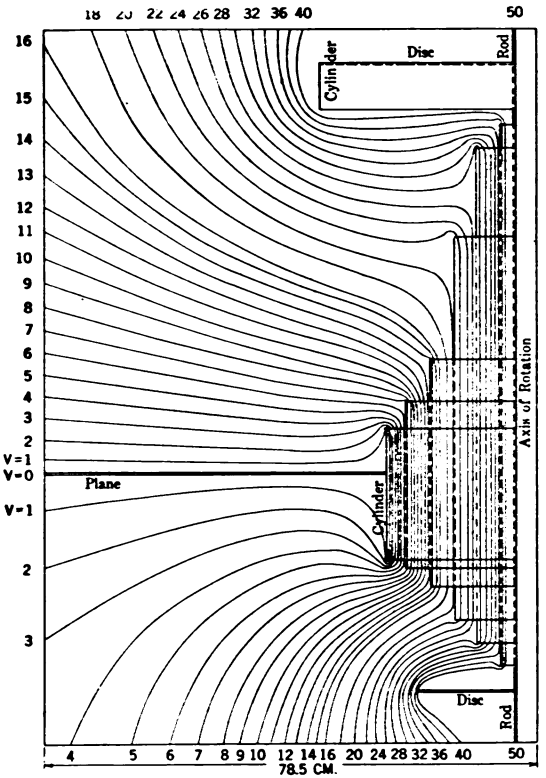


FIG. 28

which it was afterwards used. I believe that this feature is quite important. The ground shield was used in order to relieve the stress on the air above the oil level, as usual, and was projected into the air end so as to shield the joint which would be necessary in construction. Five tin quarter cylinders were then added as the artificial equipotential surfaces. These were constructed of two pieces so that they could be telescoped, thereby making it possible to change their length and the position of their ends

Digitized by Google

both in the air and oil parts of the field. The adjustment was accomplished by a system of strings so that different positions could be tried while experimenting with water in the box. The apparatus was set up in this manner and the position of the cylinders in the air and oil ends adjusted until the potential gradient between the cylinders was as nearly equal as could be easily predetermined. It was during the course of this work that it was found necessary to add the tin disk at the top of the bushing, (See Fig. 27) in order to have a dense field in which to end the two inner cylinders. If this were not done they would have had to be either too close to the under-oil disk which would mean too great a stress at the bottom of the under-oil end, or greatly extended in the air end. In the latter case the resulting bushing would have been much higher than seemed desirable for the preliminary work where an exaggeration of effects was desirable. Naturally, the position of the potential equalizing cylinders may be almost anything, that is, the potential of any of the cylinders could be brought to the desired value either by adjustment of the ends of the cylinder in the air or oil end. Such an arbitrary arrangement, without regard to the stresses brought about on other parts of the bushing, would obviously result in an impractical design. For instance, it might result in bad stresses at the ends of the cylinders and outside of them at the expense of the uniform gradient thus obtained within. In both diagrams the object was to obtain, as nearly as possible, equal gradient within the cylinders, and at the same time, obtain the best external field consistent with this requirement. Naturally, in practise it would probably be best to compromise between the internal and external parts of the field but for a preliminary study it seemed best to take one object to start with and study the consequences.

When the diagram was completed, it was found that the preliminary adjustment had not actually obtained the uniform gradient in the solid material as had been attempted. For example, the distributions between the various artificial equipotential surfaces starting from the ground shield were as follows: (See Figure 27).

I —Number of lines..... 6.
Average gradient..... $\frac{6 \text{ lines}}{2.92 \text{ cm.}} = 2.05$

II —Number of lines..... 6.4
Average gradient..... $\frac{6.4 \text{ lines}}{3.94 \text{ cm.}} = 1.62$

Digitized by Google

III —Number of lines..... 7.
Average gradient..... $\frac{7 \text{ lines}}{4.2 \text{ cm.}} = 1.66$

IV —Number of lines..... 6.5
Average gradient..... $\frac{6.5 \text{ lines}}{3.3 \text{ cm.}} = 1.97$

V —Number of lines..... 10
Average gradient..... $\frac{10 \text{ lines}}{3.8 \text{ cm.}} = 2.64$

VI —Number of lines..... 14
Average gradient..... $\frac{14 \text{ lines}}{2.16 \text{ cm.}} = 6.5$

No attempt was made to obtain a low gradient in the last case, as it was contemplated to select the equipotential surface of the inner cylinder as our rod with cap.

Inspection of Fig. 27 will show that a concentration of the field at the top and bottom ends of the bushing has resulted from forcing the nearly uniform gradient between the cylinders. It should also be observed that the capacities of the concentric cylinder condensers formed by the artificial equipotential surfaces have no definite relation, under these conditions, where the effect of the caps and assymmetry of the problem introduce large effects. For example, assuming as the length of the condensers the mean height of the two adjacent cylinders we have for the capacities starting from the ground shield.

I $C = \frac{\text{mean height}}{\log_\epsilon \frac{R}{r}} = \frac{25.2 \text{ cm.}}{\log_\epsilon 1.16} = \frac{25.2}{0.148} = 170.$

II C proportional to..... $\frac{33.3 \text{ cm.}}{\log_\epsilon 1.29} = \frac{33.3}{0.255} = 131.$

III C " " ..... $\frac{59.4 \text{ cm.}}{\log_\epsilon 1.43} = \frac{59.4}{0.358} = 166.$

IV C " " ..... $\frac{86.0 \text{ cm.}}{\log_\epsilon 1.52} = \frac{86}{0.419} = 205.$

V C " " ..... $\frac{94.2 \text{ cm.}}{\log_\epsilon 2.5} = \frac{94.2}{0.916} = 103.$

VI C " " ..... $\frac{100 \text{ cm.}}{\log_\epsilon 6.7} = \frac{100}{1.90} = 53.5$

Digitized by Google

I wish to emphasize caution against any conclusions which might be drawn from the above values for the capacities; for an entirely different adjustment of the lengths of the cylinders could obviously be obtained which would still give equal potential gradient between the successive cylinders and in which the capacities calculated as above would have entirely different values and interrelations.

Before leaving the discussion of this diagram it may be interesting to note that if we built a bushing along these lines; for example, if we selected equipotential surface No. 36 as our central rod with cap and equipotential surface No. 0 as plane with ground shield, corona would start at the top of the bushing at about 238 kv. effective and would probably arc-over slightly above this value. The average voltage per cm. of height of this bushing would be $\frac{238 \text{ kv.}}{70 \text{ cm.}} = 3.4$ kv. effective per cm.

Diagram, Fig. 28 was taken using the same electrode configuration except that the large skeleton cap was put in place of the small one used for Fig. 27. The position of the cylinders was adjusted with the same objects in view as for the previous diagram.

The distribution of potential between the various artificial equipotential surfaces starting from the ground shield will be seen to be as follows:

(See Diagram, Fig. 28).

I. —Number of lines..... 6.5

Average gradient..... $\frac{6.5 \text{ lines}}{3.05 \text{ cm.}} = 2.13$

II. —Number of lines.....7.

Average gradient..... $\frac{7. \text{ lines}}{3.94 \text{ cm.}} = 1.77$

III.—Number of lines..... 7.5

Average gradient..... $\frac{7.5 \text{ lines}}{3.94 \text{ cm.}} = 1.90$

IV.—Number of lines..... 6.

Average gradient..... $\frac{6 \text{ lines}}{3.55 \text{ cm.}} = 1.69$

V. —Number of lines..... 10

Average gradient..... $\frac{10 \text{ lines}}{3.82 \text{ cm.}} = 2.62$

Digitized by Google

VI.—Number of lines..... 13

Average gradient..... $\frac{13 \text{ lines}}{2.16 \text{ cm.}} = 6.0$

As before, no attempt was made to obtain a low gradient inside of the small last cylinder as it was contemplated using this equipotential surface for the rod with cap, as in the previous case.

The capacities of the adjacent cylinders considered as concentric cylinder condensers, starting from the ground shield, are as follows:

I.— $C = \ldots\ldots\ldots \frac{\text{mean height}}{\log_\epsilon \frac{R}{r}} = \frac{24.9 \text{ cm.}}{\log_\epsilon 1.17} = \frac{24.9}{0.157} = 158$

II.— C proportional to ..... $\frac{32.8 \text{ cm.}}{\log_\epsilon 1.27} = \frac{32.8}{0.239} = 138$

III.— " " " ..... $\frac{51 \text{ cm.}}{\log_\epsilon 1.41} = \frac{51.}{0.344} = 148$

IV.— " " " ..... $\frac{73 \text{ cm.}}{\log_\epsilon 1.56} = \frac{73}{0.445} = 164$

V.— " " " ..... $\frac{86 \text{ cm.}}{\log_\epsilon 2.5} = \frac{86}{0.916} = 94$

VI.— " " " ..... $\frac{99 \text{ cm.}}{\log_\epsilon 6.7} = \frac{99}{1.90} = 52$

As in the previous case, caution should be urged against hasty conclusions drawn from the above capacity values, for in this case also an entirely different adjustment would be possible in which the magnitudes and interrelations between the capacities would have very different values.

In designing a bushing from this diagram we might select equipotential surface No. 38 for the rod with cap and equipotential surface No. 0 for the plane with ground shield. A straight cylindrical shell would be added enclosing the central core and the ground shield. The resulting distribution of the potential on the air end of such a bushing would be approximately uniform. Under these conditions corona would start at the cap on the air end at about 440 kv. effective which gives an average gradient along the surface of 7.75 kv. effective per cm.

The tests made on glass cylinders in a uniform field in which the surface breakdown gradient was found to be about 9.2 kv.

Digitized by Google

I wish to emphasize caution against any conclusions which might be drawn from the above values for the capacities; for an entirely different adjustment of the lengths of the cylinders could obviously be obtained which would still give equal potential gradient between the successive cylinders and in which the capacities calculated as above would have entirely different values and interrelations.

Before leaving the discussion of this diagram it may be interesting to note that if we built a bushing along these lines; for example, if we selected equipotential surface No. 36 as our central rod with cap and equipotential surface No. 0 as plane with ground shield, corona would start at the top of the bushing at about 238 kv. effective and would probably arc-over slightly above this value. The average voltage per cm. of height of this bushing would be $\frac{238 \text{ kv.}}{70 \text{ cm.}} = 3.4$ kv. effective per cm.

Diagram, Fig. 28 was taken using the same electrode configuration except that the large skeleton cap was put in place of the small one used for Fig. 27. The position of the cylinders was adjusted with the same objects in view as for the previous diagram.

The distribution of potential between the various artificial equipotential surfaces starting from the ground shield will be seen to be as follows:
(See Diagram, Fig. 28).

I. —Number of lines..... 6.5

Average gradient..... $\frac{6.5 \text{ lines}}{3.05 \text{ cm.}} = 2.13$

II. —Number of lines.....7.

Average gradient..... $\frac{7. \text{ lines}}{3.94 \text{ cm.}} = 1.77$

III.—Number of lines..... 7.5

Average gradient..... $\frac{7.5 \text{ lines}}{3.94 \text{ cm.}} = 1.90$

IV.—Number of lines..... 6.

Average gradient..... $\frac{6 \text{ lines}}{3.55 \text{ cm.}} = 1.69$

V. —Number of lines..... 10

Average gradient..... $\frac{10 \text{ lines}}{3.82 \text{ cm.}} = 2.62$

Digitized by Google

VI.—Number of lines..... 13

Average gradient..... $\frac{13 \text{ lines}}{2.16 \text{ cm.}} = 6.0$

As before, no attempt was made to obtain a low gradient inside of the small last cylinder as it was contemplated using this equipotential surface for the rod with cap, as in the previous case.

The capacities of the adjacent cylinders considered as concentric cylinder condensers, starting from the ground shield, are as follows:

I.— $C = \ldots\ldots\ldots \frac{\text{mean height}}{\log_\epsilon \frac{R}{r}} = \frac{24.9 \text{ cm.}}{\log_\epsilon 1.17} = \frac{24.9}{0.157} = 158$

II.— C proportional to ..... $\frac{32.8 \text{ cm.}}{\log_\epsilon 1.27} = \frac{32.8}{0.239} = 138$

III.— " " " ..... $\frac{51 \text{ cm.}}{\log_\epsilon 1.41} = \frac{51.}{0.344} = 148$

IV.— " " " ..... $\frac{73 \text{ cm.}}{\log_\epsilon 1.56} = \frac{73}{0.445} = 164$

V.— " " " ..... $\frac{86 \text{ cm.}}{\log_\epsilon 2.5} = \frac{86}{0.916} = 94$

VI.— " " " ..... $\frac{99 \text{ cm.}}{\log_\epsilon 6.7} = \frac{99}{1.90} = 52$

As in the previous case, caution should be urged against hasty conclusions drawn from the above capacity values, for in this case also an entirely different adjustment would be possible in which the magnitudes and interrelations between the capacities would have very different values.

In designing a bushing from this diagram we might select equipotential surface No. 38 for the rod with cap and equipotential surface No. 0 for the plane with ground shield. A straight cylindrical shell would be added enclosing the central core and the ground shield. The resulting distribution of the potential on the air end of such a bushing would be approximately uniform. Under these conditions corona would start at the cap on the air end at about 440 kv. effective which gives an average gradient along the surface of 7.75 kv. effective per cm.

The tests made on glass cylinders in a uniform field in which the surface breakdown gradient was found to be about 9.2 kv.

Digitized by Google

per cm. indicate that the air end of this bushing is about as short as practical assuming good surface conditions. A shell would also be added to the under-oil end of the bushing enclosing the ground shield. Inspection of the under-oil end shows a concentration of the field about the cap. Also in view of the under oil arc-over tests on glass cylinders and hard rubber it looks as if the under-oil end is about as short as possible. The diameter of this bushing is evidently larger than necessary to withstand puncture as will be readily seen by comparing the thickness of insulation used with that found in practise to be necessary.[26] It will also be observed that the ratio of external diameter to rod diameter as used in practise is considerably less than that used for these preliminary experiments where it was about 8, if we take the inner equalizer as our rod with caps. For example, the ratio between outside diameter to rod diameter varies in practise between 2.3 and 3.7. With these relatively small diameter ratios the gradient without artificial equipotential surfaces would not be very far from uniform to start with (see diagram, Fig. 10). There is, therefore, very little potential equalizing to do. In our tests, however, we have taken a ratio of about 8, which means that we have an exaggerated condition and considerable equalizing to do.

This immediately brings up the question as to whether the small diameters of the condenser bushings is due to the equalizing effect of the tin-foil layers in bringing about uniform potential gradient, or whether the effect is not largely due to the subdivision of the solid material by metallic barriers as well as the laminated structure of the dielectric itself, thereby increasing the apparent strength of the structure,(an effect analogous to the use of solid barriers, pressboard, etc.) in liquid dielectrics. This matter will be briefly discussed before leaving the subject.

It should be observed that there is no definite proper ratio between the diameters of the central rod and the hole when artificial equipotential surfaces are used in this manner. It is, however, undesirable to use too small a central electrode because this means that more redistribution of stress has to be brought about by the artificial equipotential surfaces. This in general necessitates either too long a bushing or an excessive stress at the ends. If we select a ratio of rod to hole diameter which gives more nearly equal gradient at the

26. See "Construction and Application of the Condenser Terminal", by J. E. Mateer, *Electrical Journal*, August, 1913.

Digitized by Google

edge of the hole and rod without artificial equipotential surfaces, we will have less potential equalizing to do which will probably be found advantageous.

Experimental Bushing with Artificial Equipotential Surfaces, Uniform-Field Type

A bushing of the uniform-field type was built from a photographic reduction of Fig. 28. It has been pointed out that

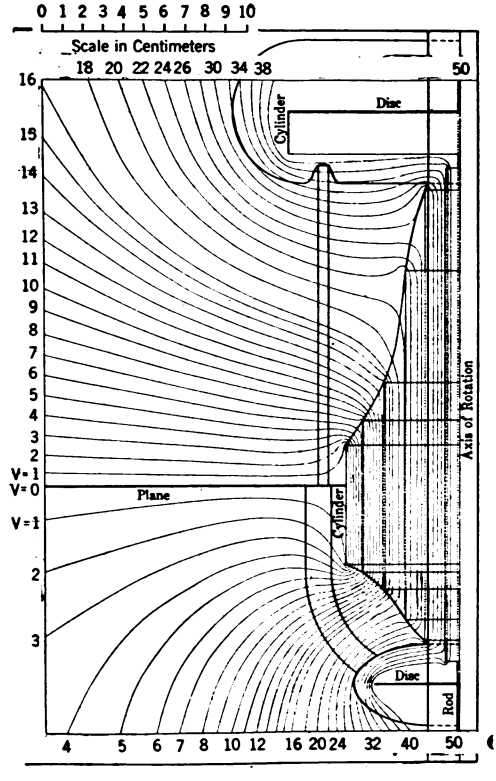


Fig. 29

in taking the diagram the artificial equipotential surfaces were adjusted so as to give an approximately uniform distribution of stress in the solid or supporting dielectric, while at the same time we attempted to produce as good an external field distribution as could be foreseen before the diagram was actually completed.

Fig. 29 shows the outline of the bushing drawn on the diagram of Fig. 28. The electrodes were not made to rigorously

Digitized by Google

conform to any of the equipotential surfaces in the diagram as it did not seem necessary to do so, since the field will probably not be greatly changed by the deviations made. A groove was put in the cap on the air end to electrostatically shield the joint between the supporting dielectric and the air. The condenser core of the bushing was made of wound-up shellac paper with tin-foil layers at intervals of 1/16 in. It was turned down to the shape shown in Fig. 29 and then stepped off as will be seen from the photograph Fig. 30.

A shellac paper cylinder enclosed the air end of the bushing and the shell for the under-oil end was built up of hard-rubber rings. Sarco, an asphaltic compound, was used as filler.

Arc Over Voltage as Calculated from the Diagram

An inspection of Fig. 29 will show that the gradient on the air end is very nearly parallel to the surface of the containing cylinder and is approximately uniformly distributed being somewhat higher near the top. The maximum gradient on the air end is seen to be on the cap away from the surface. Under these conditions corona should start on the cap at about 90 kv. effective as calculated from the diagram making allowance for the fact that the cap used did not rigorously conform to any single equipotential surface of the diagram. The bushing is 15 cm. high and therefore the average gradient along the surface would be 6.7 kv. eff. per cm.

Inspection of the under-oil end shows that a concentration of stress has resulted on the cap from forcing the uniform internal stress by the artificial equipotential surfaces. The distance between lines No. 22 and 28 (6 lines) where the under-oil shell meets the cap is 0.8 cm. thus we have 7.5 lines per cm. Tests on the under-oil arc-over of rubber cylinders between parallel planes gave a surface arc-over gradient of about 23 kv. effective per cm. Assuming this data to apply in this case arc-over of the under oil end of the bushing should take place at

about $\frac{30}{7.5} \times 23 = 92$ kv. effective.

It will be observed from these calculations that the air and under-oil ends are about equally strong. Before the tests were made it was therefore doubtful which end would arc-over first as the calculations are necessarily only approximate, since we have not actually followed the equipotential surfaces of the diagram.

Digitized by Google

Sixty Cycle Dry Arc-Over Tests

These tests were made with the plane grounded:

Arc over voltage.....86 kv. effective
Average gradient along surface..... 5.7 kv. per cm.

Arc-over took place clear of the surface from the cap to the plane. Upon applying the voltage for the third time the bushing apparently punctured either inside of the shell or under oil at 76 kv. effective. Inspection did not indicate an under-oil arc-over and therefore the bushing had to be taken to pieces in order to determine the cause of failure. This process necessitated destroying the bushing as it is difficult to get the compound out in any other way. The investigation showed that the result of failure was due to an arc-over of the bushing on the air end along the inside surface of the containing shell. A large blister about 1½ in. (4 cm.) long was found at this point which had held the compound away from the surface and thus left an air pocket which weakened the inside surface and resulted in the failure.

I was disappointed not to be able to obtain wet arc-over, impulse arc-over and under oil arc-over, but did not believe that these results would warrant rebuilding a bushing of this sort for it is quite certain that the results would be low, for the same reasons which were met with in the tests on the high-air-efficiency bushing and from which it was concluded that a more nearly radial type of field is generally desirable in practise.

A reference to Fig. 10, will show that in the radial-field type of bushing the natural equipotential surfaces are approximately cylindrical in form and therefore it will be impossible to produce any considerable change in the potential distribution by means of cylindrical artificial equipotential surfaces, unless they extend to a great distance in the air end, or unless a cap or hat, or the equivalent, is provided on the under-oil end, which changes the natural equipotential surfaces from the cylindrical form, and therefore, allows us to bring about a change in potential distribution by inserting cylindrical artificial equipotential surfaces. That is, if our inserted metal equipotential surfaces do not differ in form from the naturally existing equipotential surfaces no effect in the potential distribution results from their insertion, regardless of number, spacing, etc. It is, therefore, useless to employ them unless they produce an effective increase in the apparent strength of the solid or supporting dielectric by virtue of a subdivision of the dielectric into

Digitized by Google

elements. The following preliminary tests were, therefore, undertaken to check up this point.

Effect of Barriers on Strength of Insulation

It is well known that the strength of dielectrics decrease with increase in thickness. I believe that Lord Kelvin was the first to observe this effect for the case of air[27] in 1860.

For example, assume that we have two parallel plane electrodes with such a gradual curvature at the edges that the gradient is always less at the edges than that in the uniform part of the field. If we then take measurements of the voltage required to breakdown various thicknesses of air, we find that the apparent strength of air as determined by the potential gradient necessary to cause breakdown decreases as we increase the spacing of the planes. At exceedingly small spacings the potential gradient required to produce breakdown may be very great, for example, tests recently made by F. W. Peek, Jr.,[28] using 2.54 cm. diam. spheres at 0.0035 cm. spacing gave as the disruptive gradient 150 kv. effective per cm. As we increase the spacing the breakdown gradient for air apparently approaches a constant value of approximately 21 kv. effective per cm. at normal temperature and pressure.

De La Rue and Müller investigated this effect[29] for various spacings of parallel plane electrodes at constant pressure and temperature as well as the variation under constant spacing and varying pressure and concluded that, "The law of the hyperbola holds equally well for a constant pressure and varying distance as it does for a constant distance and varying pressure; the obstacle in the way of a discharge being as the number of molecules intervening between the terminals up to a certain point." Harris[30] had previously found that a change in air density pro-

24. Measurement of the electromotive force required to produce a spark in air between parallel metal plates at different distances. Proceedings Royal Society, Feb. 23 and April 12, 1860, or *Philosophical Magazine*, 1860, or Papers on Electrostatics and Magnetism, p. 247–259 Lord Kelvin. An account of these tests will also be found in, Electricity in Gases, J. S. Townsend, p. 346.

28. Law of Corona and Dielectric Strength of Air, III., F. W. Peek, Jr., A. I. E. E., Trans., 1913, Vol. XXXII, Part II, p. 1767.

29. Experimental Researches on the Electric Discharge with the Chloride of Silver Battery. Phil. Trans. Royal Society, Part I, 1880, p. 79–83.

30. W. S. Harris, Phil. Trans. Royal Society, 1834, p. 230.

Digitized by Google

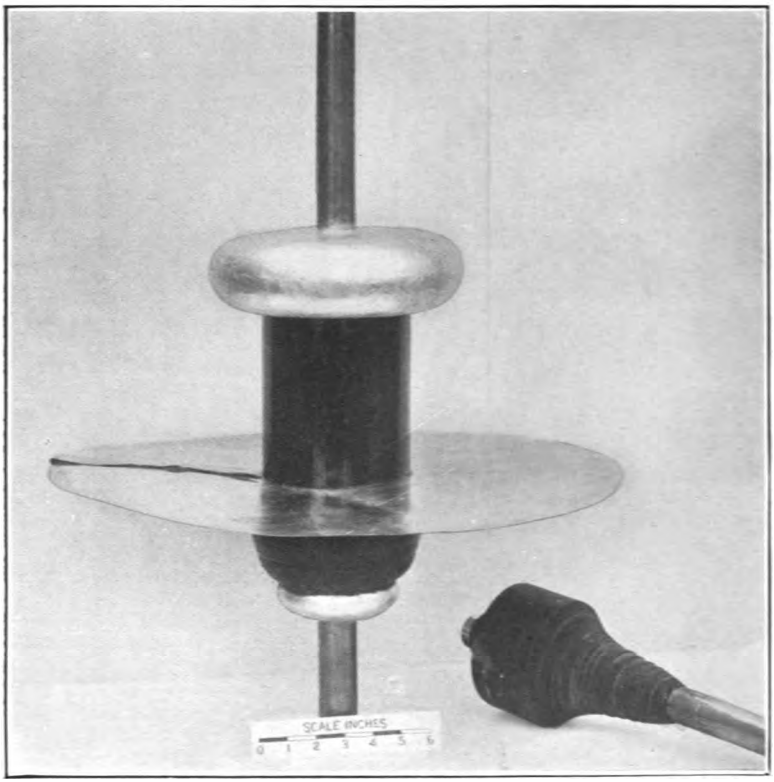


FIG. 30 [RICE]

Digitized by Google

Digitized by Google

duced the same effect whether due to temperature or pressure, that is, when air is contained in an air-tight receiver, so that the density remains constant the potential difference between two electrodes required to produce a discharge was unaltered when the temperature varied from 50 deg. fahr. to 300 deg. fahr.

If we immersed our electrodes in oil we would obtain a similarly shaped curve showing the relation between the disruptive gradient and spacing. The constants in the equations for air and oil would probably, however, be different. Again if we imagine our parallel plane electrodes embedded in some solid dielectric, for example glass, we would obtain a similarly shaped curve. For very great and very small spacings it is quite possible that all materials have the same apparent strength.

Now, if we assume that our dielectric is homogeneous and isotropic and is a perfect dielectric in every respect (no conduction, dielectric losses, etc.,) the equipotential surfaces for equal differences of potential would be equally spaced between our parallel planes. If we desired we could put in infinitely thin conducting sheets at any desired intervals without in any way changing the problem from a purely electrostatic point of view. For convenience we could space them at equal intervals so that the dielectric between any two adjacent metal equipotential surfaces between the planes was subjected to the same potential gradient. If we wished we could also metallically connect the inserted metal sheets to equal intervals on a balancing resistance shunted across our parallel plane electrodes, that is, connect the equipotential surfaces to a source of potential having the value naturally existing. Obviously nothing has been changed electrostatically by any of these processes and therefore it is evident that we can confine our attention to the dielectric included between any two equipotential surfaces, and if we now raise the potential between our parallel plane electrodes the potential gradient on the dielectric between the two equipotential surfaces which we have selected to watch will increase until finally breakdown will occur when the gradient exceeds a certain value called the strength of the material. It is observed that nothing has been said about the actual thickness of the section of the dielectric between our two metal equipotential surfaces under observation. In other words, we might in one case insert a great number of equipotential surfaces dividing the dielectric into exceedingly thin layers and in another case use fewer metallic surfaces and have thicker insulation under observation. When considering ideal dielectrics from a purely electrostatic point of view, as here

Digitized by Google

described, I think that it is clear that the actual thickness of the dielectric should have no influence upon the breakdown strength. For it should not make any difference whether we inserted isolated thin metal equipotential surfaces or left them out or inserted them and connected them to a proper source of potential. Nothing that we could detect from a purely electrostatic view point has been changed. It is also interesting to observe that a uniform leakage current should not affect these conclusions provided the heating effects were taken care of, since the equipotential surfaces for current flow would coincide with the electrostatic equipotential surfaces and no potential distortion would result.

The fact that we observe a difference in the apparent strength of dielectrics with different thicknesses, which is contrary to the above electrostatic reasoning, based on the assumption that the metal equipotential surfaces could be inserted without changing the breakdown strength, makes it interesting to determine what does take place in practise when a dielectric is divided up in this manner. Obviously when we consider the case of the metallic equipotential surfaces connected to the proper sources of potential, the breakdown strength must be the same for a given spacing between the surfaces or thickness of dielectric, no matter how many are connected in series, or what is the same thing, regardless of the total thickness of insulation under test, for each element forms a separate test piece isolated between the two metal surfaces and connected to a definite potential. The interesting thing therefore is a comparison of the dielectric strength of a given thickness of insulation with and without isolated metallic barriers placed at various spacings.

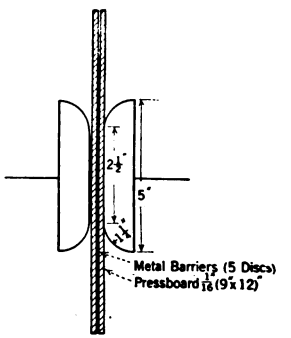


FIG. 31—ARRANGEMENT OF PRESSBOARD AND BARRIERS

I am sorry that the experimental results, which I have to offer, are so crude and incomplete, but if they will serve the purpose of starting some one on a more complete investigation of this subject I will regard them as having served a good purpose. I believe that a complete investigation of this subject would lead to a great deal better understanding of the true mechanism of the breakdown of insulations, or the theory of ionization by

Digitized by Google

collision which of course offers a qualitative explanation of the phenomena.

Tests to Determine the Effect of Barriers on Solid and Gaseous Insulation Under Uniform Field Conditions

The first set of tests recorded below in Table I were made on sheets of oiled pressboard 1/16 in. (0.16 cm.) thick. The barriers and pressboard were sealed together under No. 6 transil oil and then placed between the parallel plane electrodes as shown in Fig. 31, the whole then being immersed under No. 6 transil oil at 25 deg. cent. for test.

The object of using solid metal barriers and comparing their effect with wire-gauze barriers was to see whether the mean velocity of the particles or ions in the solid dielectric, which must precede rupture, was sufficiently high to allow an appreciable number, to pass through the openings in the gauze, whereas they should all be stopped by a metal sheet. Electrostatically the gauze should not be essentially different from the solid metal sheet.

TABLE I

Instantaneous 60-cycle puncture tests in No. 6 transil oil at 25 deg. cent. on dried 1/16 in. oiled pressboard. The average of 5 readings are given. A maximum variation of ± 2 kv. existed between individual raedings.

No. of sheets of pressboard each 0.16 cm. thick	60-cycle puncture kv. effective	Average gradient kv. eff. per cm.	Number of isolated barriers.
1	70.5	445.0	no barriers
2	113.0	355.0	" "
3	164.5	345.0	" "
2	117.0	368.0	1 tin barrier
2	124.0	390.0	Fine copper gauze
2	121.0	380.0	Coarse copper gauze

The points of puncture were well distributed over the surface of the insulation and in no cases occurred at the edge of the barriers. Contrary to the expectation the gauze barrier seems to be more effective than the tin barrier but the tests are so fragmentary that conclusions are not safely drawn. If, we attempted to use larger thicknesses arc-over occurred around the edge of the pressboard before puncture. A more satisfactory method of test was, therefore, sought. The method decided upon consisted in setting up a series of parallel plane electrodes as shown in Fig. 32, the sheet insulation being placed between the

Digitized by Google

several electrodes in series. Thus, each pair of electrodes which are connected together may be considered as a barrier. It is also possible, under these conditions, to have the barriers isolated or connected across a proper balancing resistance. An additional barrier can be placed midway between each pair of electrodes without fear of distorting the field.

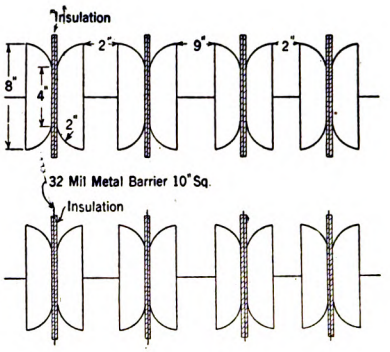


FIG. 32

A great difficulty with this method is the unbalancing of stress which the capacity or electrostatic flux to ground of the various electrodes will introduce. It was hoped that possibly this effect would not be appreciable when using fairly high inductive capacity material for the tests, as the capacity between the

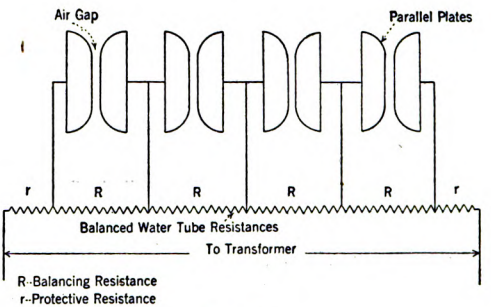


FIG. 33

electrodes proper would then be large in comparison with that to ground. A few tests made with one end of the series grounded and compared with the case in which the electrodes were isolated, in which case the neutral or ground potential would be in the middle of the series, shows a rather large effect which means that

Digitized by Google

the isolated tests are subject to voltage distortion from this cause though to a less extent than when one end was grounded.

Fig. 32 shows the arrangement of barriers and insulation for four and eight isolated barriers respectively. When it was desired to metallically connect the barriers to the proper potential, water tube resistances were used of such a value as to allow 7 to 10 times the capacity current to flow (see Fig. 33). The maximum variation of the individual resistance tubes was about 2 per cent. The apparatus was placed at about 42 in. above the floor of the room and the gap line parallel to the ground. The tests were made in No. 6 transil oil (40 kv. flat electrodes 0.2 in. (0.51 cm.) gap, 0.5 in. (1.27 cm.) diameter) at 25 deg. cent.

The insulation used was 12 mil black varnished cambric the individual sheets being sealed to each other under oil. When the balancing or shunted resistance was connected the voltage readings were corrected for the drop in the protecting resistances. The results are tabulated in Table II.

TABLE II

Instantaneous 60-cycle tests on 12-mil black varnished cambric immersed in No. 6 transil oil at 25 deg. cent. Terminals 4 in. plane with 2 in. radius at edge. Individual readings differed by ± 1 kv.

Variation of Insulation Strength with thickness or number of layers.

Average of five readings

Using one pair of planes

No. of sheets	Total thickness insulation cm.	60-cycle kv. effective	Kv. per cm. effective
1	0.031	16.5	540.0
2	0.061	29.7	480.0
4	0.122	51.5	422.0
8	0.244	92.5	378.0
16	0.488	138.3	284.0

Data repeated using four pair of planes connected in parallel to obtain the effective strength when larger areas are used and therefore greater chances for weak spots.

Average of two readings.

1	0.031	14.7	482.0
2	0.061	28.5	451.0
4	0.122	51.3	421.0
8	0.244	91.7	376.0
16	0.488	136.5	280.0

Digitized by Google

Effect of Isolated Barriers on Puncture Strength of Insulation.

Condition of test	Total thickness insulation under test cm.	Thickness between barriers cm.	Non-Grounded			One End Grounded	
			Puncture kv. eff.	Kv./cm.	Kv./cm. roughly corrected	Puncture kv. eff.	Kv./cm.
2 sheets between each of 4 planes in series	0.244	0.061	106.8	438.0	521.0	86.8	355.0
1 sheet between each of 8 barriers in series	0.244	0.031	105.8	434.0	516.0	....	....
4 sheets between each of 4 barriers in series.	0.488	0.122	168.5	345.0	411.0	....	....

Effect of Barriers when Shunted by High Resistance on the Puncture Strength of Sheet Insulation

2 sheets between each of 4 barriers in series. Each unit shunted by 8×10^5 ohms.	0.244	0.061	112.6	462.0	433.0	98.1	403.0
1 sheet between each of 8 barriers in series. Each unit shunted 4×10^5 ohms	0.244	0.031	110.0	452.0		....	....
4 sheets between each of 4 barriers in series. Each unit shunted 8×10^5 ohms	0.488	0.122	195.8	402.0		....	....

In order to obtain an estimate of the unbalancing due to the capacity of the parallel planes to ground in this method of determining the effect of barriers on the strength of insulation the following tests were carried out using air as the dielectric. Two

Digitized by Google

sets of tests were tried, the first using ½ in. (1.27 cm.) spacing between the individual planes and for the second ¼ in. (0.635 cm.) gap was used. The gaps between the individual pairs of planes were set as accurately as feasible and individual spark-over readings taken non-grounded and with one end grounded. The gaps were then all connected in multiple to check the strength of this combination as compared with the weakest gap. After doing this they were connected in series and arc-over taken both grounded and isolated with and without shunted balancing resistance. A summary of the data is given in Table III.

From other sources we know that the strength of air for large spacings (*i. e.*, 2 in. or 5.1 cm.) between parallel planes is about 21 kv. eff. per cm. Whereas these data show an average of 18.1 kv. eff. per cm. when the tests were made nongrounded and 14.2 kv. eff. per cm. for the grounded case. That is, when using air as our dielectric with this arrangement we have an increase in stress of $1 - \frac{18.1}{21.} = 14$ per cent brought about by unbalance of voltage due to capacity to ground, etc. When operating with one side grounded we have $1 - \frac{14.2}{21} = 32$ per cent or approximately twice the ill effect.

This immediately gives us a rough method of correcting the previous tests for this unbalancing effect where no balancing resistance was used. We may write the following from the data given in the table for isolated barriers.

$1 - \frac{438}{x}$ = per cent apparent decrease in strength of insulation assumed due to capacity to ground for the non-grounded tests.

$1 - \frac{355}{x}$ = per cent apparent decrease in strength of insulation for grounded tests.

Where

x = assumed true strength of the material.

If we further assume that the apparent decrease for the grounded tests is twice the decrease for the non-grounded tests as shown to be approximately the case in air, we can write

$$2\left(1 - \frac{438}{x}\right) = \left(1 - \frac{355}{x}\right)$$

$x = 521$ assumed true strength of the material.

Digitized by Google

TABLE III

½-INCH GAP

Relative Humidity 40 per cent. Bar. 76 cm. Temp. 25 deg. cent.

Condition of test	Non-Grounded		Grounded	
	60-cycle kv. eff.	Kv./cm. eff.	60-cycle kv. eff.	Kv./cm. eff.
Gap 1 ½ in.	26.3		26.3	
2	26.3		26.3	
3	26.5		26.4	
4	26.4		26.4	
Ave.	26.4	20.8	26.4	20.8
Four gaps in multiple..	26.3	20.7	26.3	20.7
Four gaps in series.	87.5	17.2	69.5	13.5
Four gaps in series each shunted by 7×10^5 ohms.....	106.0	20.8	106.0	20.8

¼-INCH GAP

Temp. 20 deg. cent. Bar. 76 cm. = 1.00

Condition of test	Non-Grounded		Grounded	
	60-cycle kv. eff.	Kv./cm. eff.	60-cycle kv. eff.	Kv./cm. eff.
Gap 1 ¼ in.	13.9	22.0		
2	14.1	22.2		
3	13.8	21.8		
4	13.9	22.0	14.0	22.1
Average	13.9	22.0		
Four gaps in multiple (arc-over No. 3)...	13.8	21.8		
Four gaps in series.	48.5	19.0	38.0	15.0
Four gaps in series each shunted by 8.5×10^5 ohms with 1.4×10^5 protective resistance.....	52.0	20.5	51.0	20.1

Averaging the data for ½ in. and ¼ in. spacings.

Four gaps in multiple		21.2		
Four gaps in series.		18.1		14.2
Four gaps in series each shunted by resistance.....		20.7		20.4

Digitized by Google

The strength as indicated from the tests was 438 kv. effective per cm. or only 84 per cent of the value obtained after applying this rough method of correction. I have also applied the same correction factor to the rest of the values in this part of the table. We might consider the corrected column as an upper limit and the data as observed from test as a lower limit to the true value. In that case the average of these two columns would give another estimate of the strength as affected by barriers.

When considering the tests using air dielectric in which balancing resistances were used we see that the stress due to capacity to ground is practically eliminated. It should also be noted from these tests that there is no appreciable increase in stress analogous to that which has been discussed for the case of two spheres in space where it was seen that even though there is no potential unbalance between the spheres, there is nevertheless considerable increase in stress when one sphere is at zero potential and the other at a given high potential, over the case in which they are both isolated and have the same difference of potential between them.

Therefore, it would seem that the best method of estimating the true strength of the insulation when balancing resistances are used is to average directly the non-grounded tests with the grounded tests. The data obtained is not sufficiently extensive to enable us to see whether there is a real difference between these two cases or not.

TABLE IV

AVERAGE OF DATA

Thickness of insulation No barriers. cm.	Thickness of insulation between barriers. cm.	Average strength of material No barriers. Kv. eff./cm.	Strength of material with barriers average isolated and shunted kv. eff./cm.
0.031	0.031	511	467
0.061	0.061	466	464
0.122	0.122	422	386

In conclusion it appears probable from a theoretical point of view that the strength of insulation under uniform field conditions is the same whether the barriers are isolated or connected

Digitized by Google

metallically to the proper sources of potential and also that the strength merely depends upon the thickness of the material between the barriers. The averages, as given in the above table, do not warrant the above conclusions, but I am inclined to believe that the discrepancy is due to insufficient data and errors in the method. I hope, therefore, that someone will take up the subject and make a careful study of this important theoretical and also practical problem.

Another interesting question would be to determine the limiting value of the electrostatic flux density which would result in excessive heating, and therefore, breakdown irrespective of the so-called "instantaneous strength" of the structure. The effect of metal barriers in distributing the heating, eddy-current losses in the metal barriers due to electromagnetic flux accompanying the charging current, etc., would also be of interest.

General Discussion of the Problem of High Voltage-Bushing Design

So far we have considered the problem of high-voltage-bushing design mainly from an ideal and purely electrostatic point of view, that is, we have greatly simplified the problem by assuming ideal or perfect dielectrics and a constant or static condition of the equipotential surfaces. These conditions do not however, actually exist in practise, and therefore, the effects brought about by rain, dirt, snow, steep wave front impulses must be considered in a complete theory of the correct and most effcient design.

For example, under rain conditions the equipotential surfaces are in a general constantly changing and will be different from the dry condition. There is probably also a certain space or volume charge effect due to the rain drops becoming charged from contact with the high potential electrodes and then falling in the vicinity of the bushing to the grounded electrode. Furthermore, a considerable change in the electrostatic field may be brought about by an effective increase in the permittivity of the air part of the dielectric due to the presence of small rain drops. The problem is further complicated by the presence of conduction over wet or dirty surfaces with the consequent change in the potential distribution as well as the possibility of an arc-over resulting from what might be called fuse action that is, the conducting material may become over-

Digitized by Google

heated by conduction and blow like a fuse and thus precipitate an arc-over along the path of the hot gases.

There are a great many other disturbing factors and possibilities which have not been mentioned, but I believe that the above are sufficient to show the multitude of factors over which the designer can have no control and which, therefore, must be included in the theoretically correct and most efficient bushing design.

We have already observed the large surface effect which exists even with relatively clean dry surfaces, also the change in the dielectric strength of materials when subdivided into thin layers by metal barriers and probably, to some extent, merely by laminating the material.

It might appear from what has been said about the complexity of the problem that it is beyond the power of analysis to try to obtain a complete theory of bushing design. Strictly speaking, I believe that this is the case, nevertheless, I believe that the incomplete theory which we have is of great value in determining the proper lines along which to experiment.

We will now briefly describe the construction and tests on a series of small experimental bushings which were built for the purpose of determing the rain and dry characteristics of various types.

The object was to determine the general type of bushing which would best meet the following conditions.

I. Rain and dry arc-over should have as nearly as possible the same value.

II. The arc-over of the under-oil end should be considerably above either the rain or dry-air end arc-over.

III. Puncture should occur considerably above the under-oil arc-over.

IV. The impulse safety factor or ratio should be as high as possible, both under wet and dry conditions and application of a large number of impulses should not result in puncture.

The materials used in the construction of these bushings were selected from the point of view of ease of construction and alterations. The caps used on the air and oil ends were turned up of wood and metal covered by the Schoop metal spraying process. After completing the tests with a certain shape of cap it could be put in a lathe and altered in the desired manner and then re-metallized. Hard rubber was selected as the material for the core since it can be readily machined to any desired

Digitized by Google

form; for example, the necessary protection of the edges of the ground shield was easily obtained (see Fig. 34). This material also has other desirable qualities such as homogeneity, high dielectric strength, small surface effect.

A single glass tube was used for the containing shell in order to eliminate the difficulty of making oil tight joints. The only joints being that at the lower cap which was satisfactorily sealed with ceresine. A glass seal was provided by which connection was easily made between the ground shield and the tin disc which

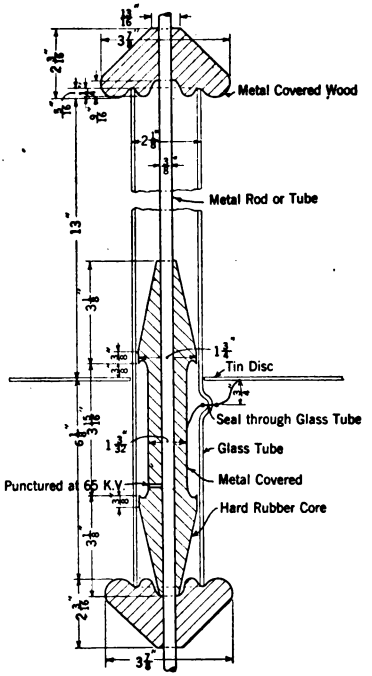


FIG. 34

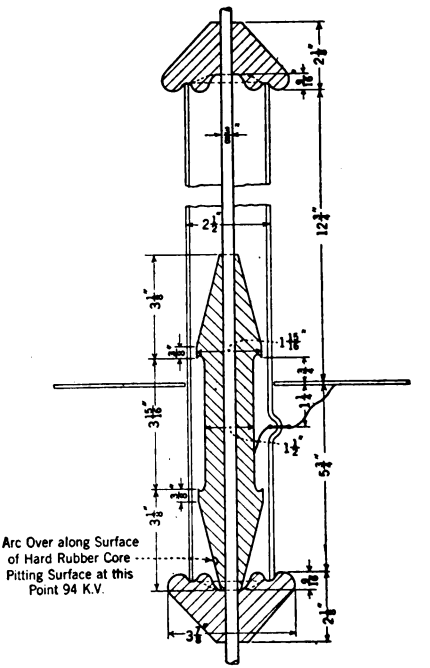


FIG. 35

represents the transformer tank cover. For convenience, a transparent Russian mineral oil was used as filler. During tests the under-oil end was placed in a 5-gallon tin can filled with oil, having dimensions 9 in. by 9 in. by 14 in. high. All tests were made at 60 cycles and with the tin can and tin disc connected together and grounded.

Determinatoin of Puncture and Under-Oil Arc-Over

This series of tests were made to determine the under-oil and puncture characteristics of the bushings.

Digitized by Google

Bushing No. 1. A bushing was built up as shown to scale in Fig. 34. The joints between the glass containing cylinder and the metal caps were shielded by the grooves as shown. The joint between the hard-rubber core and cap on the under-oil end was likewise protected. The electrostatic field of the under-oil end is practically of the uniform-field type (Fig. 14), the desirability of which has been pointed out. The air end is essentially the radial-field type.

In test this bushing punctured at 65 kv. effective at the point shown in Fig. 34. After sawing the core open longitudinally, inspection showed that the hole had not been smoothly drilled which may have accounted for the puncture, as the space thus left between the rod and core may not have been properly filled with oil.

Bushing No. 2. (See Fig. 35). The core was increased to 1½ in. (3.8 cm.) external diameter so as to insure a safe margin against puncture. As an additional precaution a brass tube closed at the bottom end and having small holes drilled radially at intervals inside the core was used in place of the brass rod used in Bushing No. 1. The object being to enable oil poured in at the top of the tube to fill up any irregularities resulting from imperfect fit between the core and central rod.

In test this bushing arced over along the surface of the hard rubber and jumped to the inner guard ring on the cap at 94 kv. effective. Small chips were taken out of the rubber at the point shown in Fig. No. 35, apparently where the surface arc turned to jump to the guard ring.

Bushing No. 2-*A*. Bushing No. 2 was disassembled and the inner guard ring cut down to the shape shown by the dotted lines in Fig. 35. In assembly the core was inverted putting the damaged part toward the air end of the bushing, bringing the new end under test.

Arc-over occurred over the surface of the hard rubber core on the under-oil end without pitting the surface at 93.5 kv. effective. The voltage was then brought up again and arc-over occurred over the surface of the hard-rubber core on the air end to the previously damaged spots and there punctured to the rod at 82.5 kv.

Bushing No. 3. (See Fig. 36). The hard-rubber core, which had been damaged by the previous tests, was turned down to the form shown in Fig. 36, thereby removing the damaged material. The under-oil end cap was also altered to a form

Digitized by Google

approximately as shown. Practically the only electrostatic change made by this alteration was to somewhat reduce the shielding effect of the cap on the hard rubber core. The air end was also materially shortened.

This bushing arced-over the air end at 81 kv. Upon bringing up the voltage a second time arc-over occurred over the surface of the hard-rubber core on the under-oil end without damaging the core at 86.5 kv. effective.

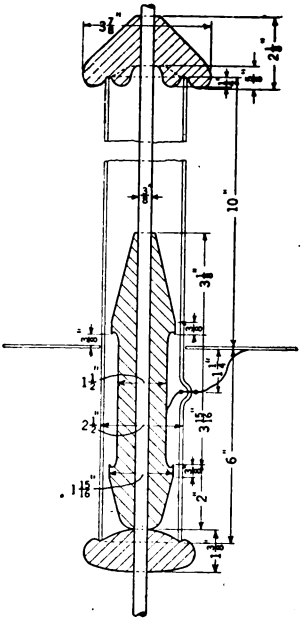


FIG. 36

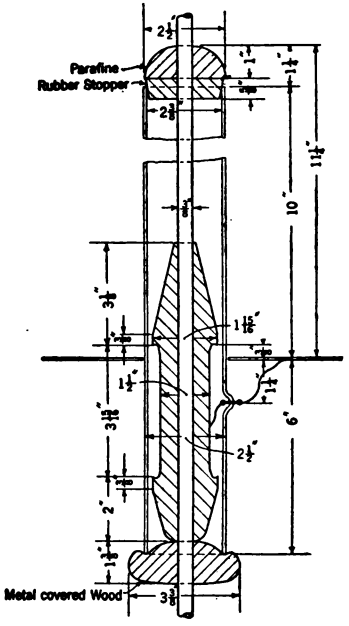


FIG. 37

Determination of the Air-End Characteristics

Having secured a fairly efficient and satisfactory under oil end the work was then directed towards a study of the rain and dry characteristics of various air-end combinations.

Further Tests on Bushing No. 3. (See Fig. 36.)Temp. 24 deg. cent. Barometer 76 cm. Humidity 57 per cent.

Bushing Dry

Corona visible air end near ground shield	41 kv.
Corona visible on cap of air end	59 kv.
Bushing outlined air end	87 kv.

Arc-over was not taken.

Digitized by Google

Rain about 0.2 in. per minute at 45 deg.

Corona starts top and bottom	10 kv.
First streamers	16 kv.
Whole tube outlined	20 kv.
Arc-over	52 kv.

This bushing is obviously unsatisfactory because of the low corona starting points both wet and dry and the very low rain arc-over.

Bushing No. 4. (See Fig. 37). This bushing was similar to No. 3 except that the metal cap at the top was replaced by a rubber stopper covered with paraffine. The object being to make the field on the air end as nearly radial as possible.

Summary of Tests on Bushing No. 4

Temp. 23.5 deg. cent. Barometer 76 cm. Hum. 50 per cent.

Bushing Dry

Corona starts near ground shield	35 kv.
Corona at top and bottom	60 kv.
Voltage raised without arc-over to	85 kv.

Rain Test about 0.2 in. per minute 45 deg.

Corona starts top and bottom	15 kv.
Tube outlined	17 kv.
Vicious streamers over surface	34 kv.
Arc-over	57 kv.
Arc-over (paraffine removed)	55 kv.

This bushing is unsatisfactory for the same reasons as stated for No. 3.

Bushing No. 5. (See Fig. 38). This bushing was exactly similar to No. 4 except that the internal brass shield was added as shown in Fig. 38. The object of adding this element was to somewhat relieve the stress on the rubber stopper and paraffine and to throw it away from the rod at the top of the bushing.

Summary of Tests on Bushing No. 5

Temp. 23.5 deg. cent. Barometer 76 cm. Hum. 50 per cent.

Bushing Dry

Corona starts at ground shield	32 kv.
Corona top and bottom	68 kv.
Voltage raised without arc-over to	80 kv.

Rain Test about 0.2 in per minute 45 deg.

Corona starts top and bottom	18 kv.
Arc-over	42 kv.

This bushing is obviously unsatisfactory.

Digitized by Google

Bushing No. 6. (See Fig. 39). This bushing was constructed as shown in Fig. 39. The air end was shortened and the glass tube drawn down so as to get rid of the rubber stopper and paraffine, which gave trouble in the previous two bushings by carbonization and burning. The internal shield shown was used for the same reasons as in Bushing No. 5.

Summary of Tests on Bushing No. 6.

Bushing Dry

Corona starts at ground shield and extends up the surface of glass tube	50 kv.
Corona appears opposite guard ring on the air end	77 kv.
Arc-over	79 kv.

Rain Test about 0.2 in. per minute 45 deg.

Corona starts at top near tin foil	5 kv.
Corona streamers run out from tin foil over the glass surface	10 kv.
Bushing outlined	12 kv.
Arc-over	36 kv.

Bushing No. 6-*A*. A metal cone similar to that shown in Fig. 41 was slipped over the top of bushing No. 6 and the following results obtained.

Bushing Dry

Corona on surface of glass opposite guard ring	30 kv.
Bushing outlined	60 kv.
Arc-over	78 kv.

Rain Tests approximately 0.2 in. per minute 45 deg.

Corona starts at edge of metal cone	14 kv.
Bushing outlined	20 kv.
Arc-over	29 kv.

These bushings No. 6 and No. 6-A, are seen to be unsatisfactory from the point of view of corona starting point and wet arc-over.

Bushing No. 7. (See Fig. 40). The previous tests showed the necessity of breaking up the flow of water which adheres to the smooth glass surface and thereby produces great field distortion, or a sort of short circuit, or conducting sheet over the bushing. In order to accomplish this result the usual method of adding petticoats was resorted to. These were made by belling out glass tubing as will be seen from the figures. The petticoats were then slipped over the glass shell and the intervening space filled in with ceresine. In other respects, the bushing was exactly similar to No. 6.

Digitized by Google

From an electrostatic point of view, it will be observed that in the radial-field type of bushing the corrugations approximately coincide with the direction of the flux lines. Therefore, the potential gradient is along the surface of the corrugations and will tend to break down any surface layer of dust or dirt. For this reason it would appear that their effectiveness is somewhat limited. We may further observe from Fig. 9 that when dry the presence of the corrugations will not appreciably affect the field distribution in this type of bushing, except those which are close to the tank. In this latter case they are seen to introduce an

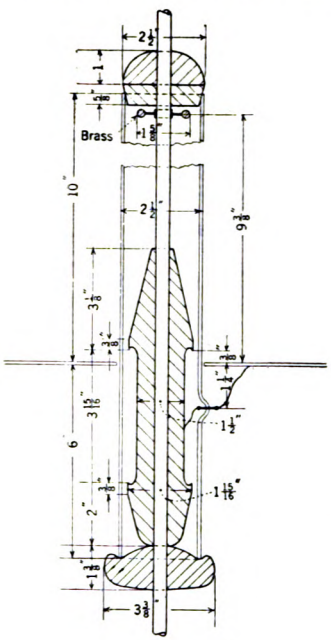


FIG. 38

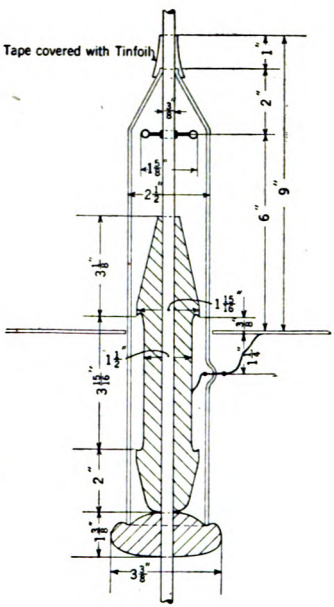


FIG. 39

appreciable percentage of high inductive capacity material in series with the air. Therefore, if petticoats of this kind are used it may be best not to extend them too near the tank.

In the uniform-field type of bushing it will be observed that the petticoats introduce high inductive capacity material in series with the air (except in case of a vacuum bushing). This means that when dry the stress on the air will be increased by their addition. The surfaces of the corrugations will lie practically along the equipotential surfaces; hence, an accumulation of dust, water, etc., would not result in so great a field distortion.

Digitized by Google

Summary of Tests on Bushing No. 7.

Humidity 60 per cent. Barometer 76 cm. Temp. 24 deg. cent.

Bushing Dry

Corona on tin-foil at top of bushing	24 kv.
Corona near ground shield	38 kv.
Bushing outlined	60 kv.
Streamers over the entire surface of glass	70 kv.

Rain Tests approximately 0.2 in. per minute 45 deg.

Corona on tin-foil at top	26 kv.
Corona on edge of upper petticoat	34 kv.

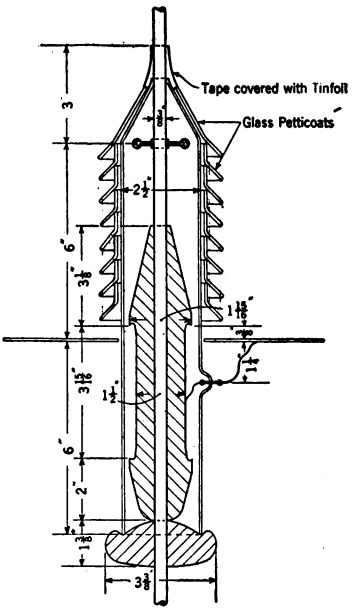


FIG. 40

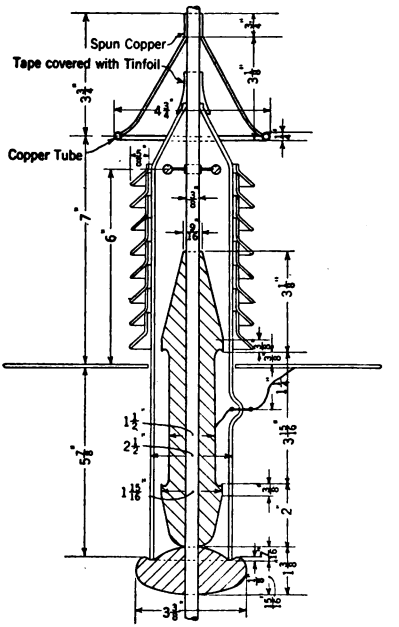


FIG. 41

Corona near ground shield	50 kv.
Corona streamers over surface	70 kv.
Arc-over	75 kv.

It will be observed that the addition of the petticoats has greatly improved the wet arc-over of the bushing.

Bushing No. 8. (See Fig. 41 and Fig. 42). This bushing is identical to No. 7 except that the spun copper cone was added in order to act as rain shed and thereby eliminate the formation of streamers which went out over the top surface of the glass in the previous bushing No. 7.

Digitized by Google

Summary of Tests on Bushing No. 8.

Humidity 60 per cent. Barometer 76 cm. Temp. 24 deg. cent.

Dry Tests

Corona near ground shield	46 kv.
Arc-over	69 kv.

Rain Test approximately 0.2 in. per minute at 45 deg.

Corona on edge of cone and near ground shield	36 kv.
Bushing outlined	43 kv.
Arc-over	69 kv.

This bushing is seen to be quite satisfactory from the point of view of wet and dry arc.

Bushing No. 9. (See Figs. 43 and 44). For this bushing a new core and caps were turned up as shown in Fig. 43; also an idea of the appearance can be obtained from Fig. 44 which is of a similar bushing. The air and oil ends were made identical except for the addition of petticoats to the air end. The method of assembly of the petticoats previously used namely to fill the space between the petticoats and glass shell with ceresine was given up. Instead the individual petticoats were cemented together with a sealing wax composition. The resulting petticoat shell was slipped over the inner containing glass cylinder and the space filled with a viscous compound. This made a more satisfactory scheme for assembly and disassembly.

Summary of Tests on Bushing No. 9

Temp. 24 deg. cent. Barometer 76 cm. Humidity 60 per cent.

60-cycle Tests

Bushing Dry

Corona on edge of upper cap	51 ± 2 kv.
Arc-over	59 ± 2 kv.

Rain Test approximately 0.2 in. per minute 45 deg.

Corona on edge of upper cap	24 ± 2 kv.
Bushing outlined	42 ± 4 kv.
Arc-over (clear of surface)	48± 5 kv.

$$\frac{\text{wet arc-over}}{\text{dry arc-over}} = 0.813$$

Impulse Tests

200 kilocycle "B" wave

Bushing Dry

Arc-over (1 out of 10 impulses)	99 kv. eff.
Arc-over (5 " " " ")	103 kv. eff.

Digitized by Google

Rain Test 0.2 in. per minute 45 deg.

Arc-over (1 out of 10 impulses)..... 93 kv. eff.
Arc-over (5 " " " ")..... 95.3 kv. eff.

Impulse ratio or safety factor

$$\text{Dry} = \frac{99}{59} = 1.68$$

$$\text{Rain} = \frac{93}{48} = 1.93$$

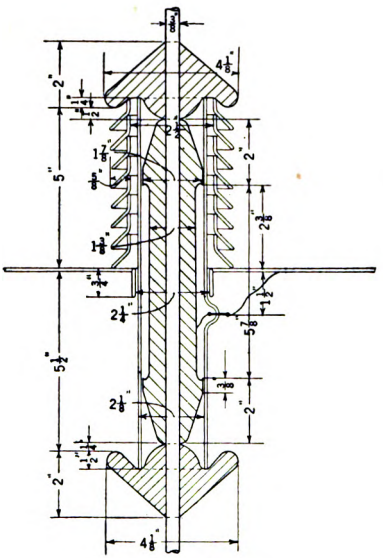


FIG. 43

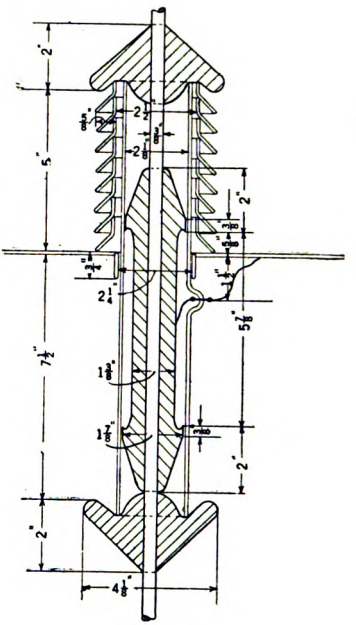


FIG. 45

Bushing No. 10. (See Figs. 45 and 46). This bushing was identical to No. 9 except that the hard rubber core was moved down to the position shown in Fig. 45, thereby changing the type of field used on the upper part of the air end from the parallel field type to a more radial type. This bushing is shown in the photograph Fig. 46.

Summary of Tests on Bushing No. 10

60-cycle Tests

Bushing Dry

Corona on edge of upper cap..... 54 ± 4 kv.
Arc-over (clear of surface)..... 64 ± 1 kv.

Digitized by Google

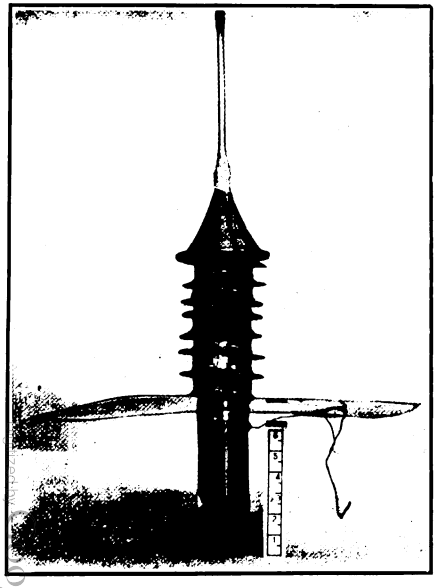


FIG. 42

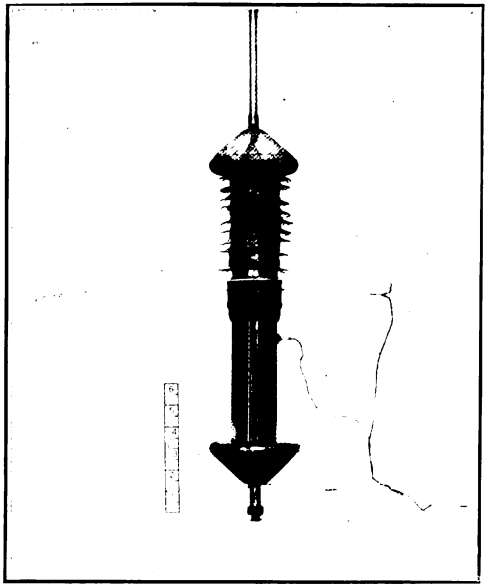


FIG. 44

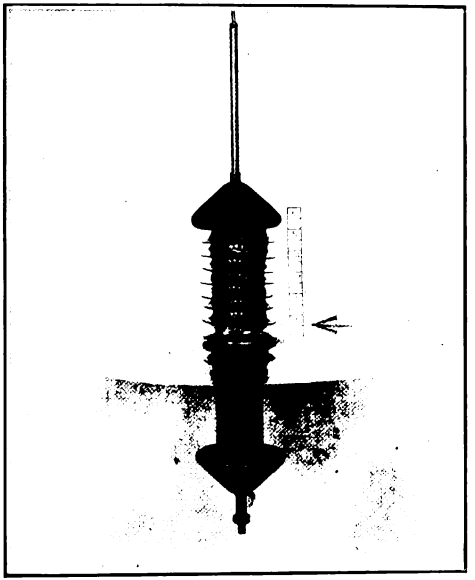


FIG. 46

Digitized by Google

Rain Test approximately 0.2 in. per minute 45 deg.

Bushing outlined	40 ± 3 kv.
Arc-over (clear of surface)	46 ± 2 kv.

$$\frac{\text{wet arc-over}}{\text{dry arc-over}} = 0.72$$

Impulse Tests
200 kilocycle "B" Wave

Bushing Dry

Arc-over (1 out of 10 impulses)	111	kv. eff.
Arc-over (5 " " ")	114	kv. eff.

Bushing Rain approximately 0.2 in. per minute at 45 deg.

Arc-over (1 out of 10 impulses)	104	kv. eff.
Arc-over (5 " " ")	107.5	kv. eff.

Impulse ratio or safety factor

$$\text{Dry} = \frac{111}{64} = 1.73$$

$$\text{Rain} = \frac{104}{46} = 2.26$$

Of this series of bushings it appears that the general form shown in Figs. 43 to 46 best fulfills the various requirements which an all around bushing has to meet.

ACKNOWLEDGMENTS

In conclusion I wish to express my appreciation of the interest which was shown by Dr. C. P. Steinmetz, Mr. G. Faccioli, and Dr. E. J. Berg in connection with the experimental part of the work and to Professor W. E. Byerly for the great assistance which he so kindly gave me in the course of the mathematical work contained in the appendix. I wish, furthermore, to acknowledge the help which Mr. B. L. Stemmons has given in making the various tests.

Digitized by Google

APPENDIX

Mathematical Solution of Two Electrostatic Problems

It is not in general possible, by known mathematical methods, to obtain the solution of Laplace's equation so as to fulfil arbitrarily given boundary conditions.[31] If, however, we take the simplest conceivable electrode arrangement which would form the skeleton of a bushing we can obtain a mathematical solution for this case. The most simple electrode arrangement will be seen to be a fine wire passing perpendicularly through a hole in an infinite plane. The mathematical formulation of these skeleton electrodes can be obtained. Thus, for instance, we can formulate the equation of an infinite plane with a hole in its centre as the focal or limiting hyperboloid of revolution of one sheet. The edge of the hole will be at the focus of the hyperboloid. We can now formulate the equation of a fine wire passing perpendicularly through the centre of the hole in our plane. It will be represented by the other limiting confocal hyperboloid, that is, the one which degenerates into the axis of revolution of the confocal family. You will readily see that we have thus reduced the problem to finding the distribution of the electrostatic field between two confocal surfaces of the same family maintained at given potentials. In this case the equipotential surfaces will be hyperboloids of revolution.

We have thus reduced our problem to a form which can be treated quite simply mathematically and for which the form of the solution is known.[32] Here Maxwell states that the equipotential surfaces will be confocal hyperboloids of one sheet and the surfaces of flow will be the confocal oblate spheroids.

The simplicity of the mathematical solution rests upon a wise selection of the coordinates as it does in many other problems of this type. For example, in dealing with cylindrical distributions we would employ cylindrical co-ordinates; in spherical distributions we would use spherical co-ordinates.

In this case where we have to deal with surfaces formed by the revolution of hyperbolas about their conjugate axis thus forming hyperboloids of one sheet; a system of cur-

31. An extremely interesting discussion of this subject will be found in Maxwell's Electricity and Magnetism, Vol. I Chap. VII, page 175.

32. See—Maxwell's Electricity and Magnetism, Vol. I, page 235.

Digitized by Google

vilinear co-ordinates of a proper form are made use of. Since most engineers are not very familiar with their meaning and use I have started from the beginning and gone through the development of the system of curvilinear co-ordinates which are used in solving our problem. This makes the work appear rather long and clumsy, but will, I believe, make the whole subject quite simple and clear, and is therefore justified. Assuming a familiarity with the system of co-ordinates, the solution is exceedingly simple, in fact it is practically as simple as the familiar solution for parallel wires at large spacing where the diameter of the wires is neglected.

CURVILINEAR CO-ORDINATES; CONICOIDS OR QUADRIC SURFACES

A surface whose equation is of the second degree in x, y and z, is called a quadric surface or conicoid. The sphere is a special case of such a surface.

It is possible, by a suitable transformation of co-ordinates, to reduce the general equation of the second degree in x, y, and z, namely;

$$Ax^2 + By^2 + Cz^2 + 2\,Dyz + 2\,Ezx + 2\,Fxy. + 2\,Gx + 2\,Hy + 2\,Iz + K = 0 \qquad (1)$$

to the following form in which the terms yz, zx and xy are all absent. That is, the equation can be put into the following simpler form;

$$A'x^2 + B'y^2 + C'z^2 + 2\,G'x + 2\,H'y + 2\,I'z + K' = 0 \qquad (2)$$

If in this equation the constants A', B', C' are all finite, we can further simplify it by making a change in the origin of co-ordinates and obtain an equation which when referred to its new axis is of the form

$$A'x^2 + B'y^2 + C'z^2 = D' \qquad (3)$$

The locus of this equation is evidently symmetrical with respect to each of the co-ordinate planes, and hence with respect to the origin. Such surfaces are therefore called central *quadric surfaces.*

We may now divide equation (**3**) through by D' and obtain

$$\frac{x^2}{\frac{D'}{A'}} + \frac{y^2}{\frac{D'}{B'}} + \frac{z^2}{\frac{D'}{C'}} = 1 \qquad (4)$$

Digitized by Google

If in (**4**) we substitute

$$a_1 = \frac{D'}{A'}, \quad a_2 = \frac{D'}{B'}, \quad a_3 = \frac{D'}{C'}$$

We have the familiar equation of a central quadric surface referred to, its principal axes, namely;[33]

$$\frac{x^2}{a_1} + \frac{y^2}{a_2} + \frac{z^2}{a_3} = 1 \qquad (\mathbf{5})$$

where a_1, a_2 and a_3 may be positive or negative. If they are all negative, the surface is imaginary. We will now consider the nature of the surfaces under the various other conditions.

First. Suppose one of the constants a_1, a_2 or a_3 is negative, while the remaining two are positive.

$$\text{Thus, let } a_3 = -c^2$$
$$\text{while } a_1 = a^2$$
$$a_2 = b^2$$

Also assume that, a, is numerically greater than b, and, b, greater than c,

or $$a > b > c$$

Substituting these values in (**5**) we obtain

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} - \frac{z^2}{c^2} = 1 \qquad (\mathbf{6})$$

This particular central quadric surface will be recognized to be that of a hyperboloid of one sheet with conjugate axis along the z axis.

This can be seen by considering the shape of the plane curves which results as the intersection of this solid figure with the reference planes, or what are generally called the principal sections of the surface. First take the X-Y plane, that is, the plane whose equation is $z = 0$. Substituting this value in (**6**) we obtain.

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$$

33. Proofs of the statements made above may be found in any good book on Solid Analytic Geometry, for example; Solid Geometry by Charles Smith,—Macmillan and Company.

Digitized by Google

That is, the surface is cut by the X-Y plane in the ellipse showe semi-axes are a and b. The foci are at a distance from the origin.

$$f = \sqrt{a^2 - b^2} = \sqrt{a_1 - a_2}$$

which is seen by inspection from Fig. 1.

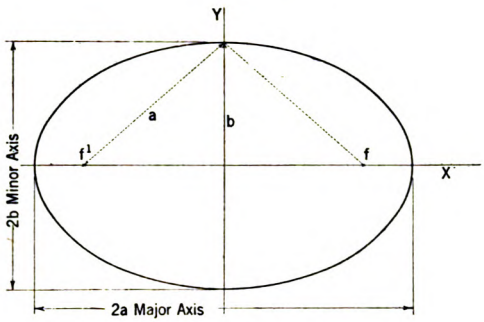


FIG. 1—ELLIPSE

The section cut out by the Z-X plane ($y = 0$) is seen to be the hyperbola

$$\frac{x^2}{a^2} - \frac{z^2}{c^2} = 1$$

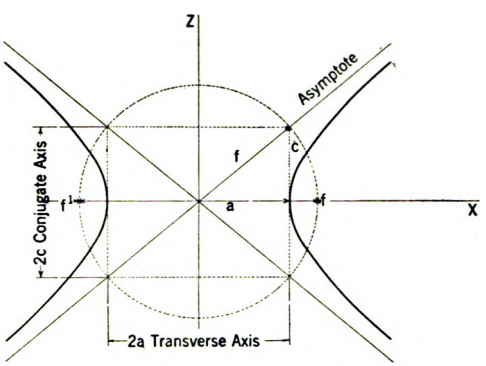


FIG. 2—HYPERBOLA

with semi-axes a and c. The foci are at the distance

$$f = \sqrt{a^2 + c^2} = \sqrt{a_1 - a_3}$$

on the X axis which can be seen by inspection from the values of the various quantities as given in Fig. 2.

Digitized by Google

The section by the Y-Z plane ($x = 0$) is the hyperbola

$$\frac{y^2}{b^2} - \frac{z^2}{c^2} = 1$$

with semi-axes b and c and foci at the distance

$$f = \sqrt{b^2 + c^2} = \sqrt{a_2 - a_3}$$

on the Y axis.

Thus the surface defined by equation (**6**) is seen to be a hyperboloid of one sheet with the conjugate axis on the Z axis.

If in the above equation (**6**) we let $a = b$ the section of the surface by any plane parallel to the X-Y plane (plane $z = K$) is a circle. Hence, the surface would be formed by the revolution of the hyperbola $\frac{x^2}{a^2} - \frac{z^2}{c^2} = 1$ about its conjugate axis. Fig. 3 shows the form of the surface.

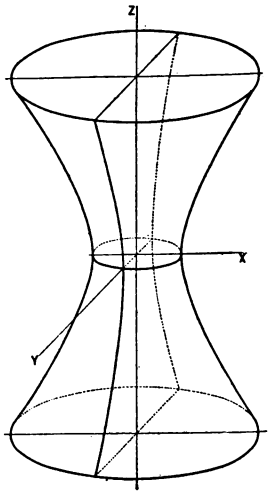


FIG. 3—HYPERBOLOID OF ONE SHEET

Second. Let two of the constants a_1, a_2, a_3 in equation (**5**) be negative.

For example, let

$$a_2 = -b^2$$
$$a_3 = -c^2$$
$$a_1 = a^2$$

Also assume as before that a is numerically greater than $b$and b greater than c,

$$\text{or} \quad a > b > c$$

Substituting these values in (**5**) we obtain,

$$\frac{x^2}{a^2} - \frac{y_2}{b^2} - \frac{z^2}{c^2} = 1 \qquad (7)$$

and the surface is called a hyperboloid of two sheets.

The sections by the co-ordinate planes and their focal distances are found as before.

Digitized by Google

The section by the X-Y plane ($z = 0$) is the hyperbola

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

with semi-axes a and b and focal distance

$$\sqrt{a^2 + b^2} = \sqrt{a_1 - a_2}$$

The section by the ZX plane ($y = 0$) is the hyperbola

$$\frac{x^2}{a^2} - \frac{z^2}{c^2} = 1$$

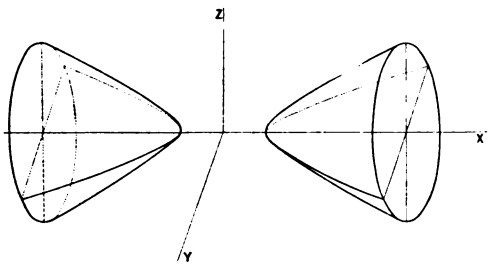


FIG. 4—HYPERBOLOID OF REVOLUTION OF TWO SHEETS

with semi-axes a and c and focal distance

$$\sqrt{a^2 + c^2} = \sqrt{a_1 - a_3}$$

The section by the YZ plane ($x = 0$) is the imaginary ellipses $\frac{y^2}{b^2} + \frac{z^2}{c^2} = -1$. With semi-axes b and c and focal distance

$$\sqrt{-(b^2 - c^2)} = \sqrt{a_2 - a_3}$$

If in equation (7) we let $b = c$ the section by any plane parallel to the plane $x = 0$ is a circle. Hence the surface is in this case formed by the revolution of the hyperbola

$$\frac{x^2}{a^2} - \frac{y^2}{b^2} = 1$$

about its tranverse axis. The form of the surface is shown in Fig. 4.

Digitized by Google

Third. Let all of the constants a_1, a_2 and a_3 be positive. Thus, let

$$a_1 = a^2$$
$$a_2 = b^2$$
$$a_3 = c^2$$

Also let us assume that the relative magnitude of the constants are as indicated by the equation

$$a > b > c$$

Upon substituting these values in equation (**5**) we obtain

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1 \qquad (8)$$

which is seen to be the equation of an ellipsoid.

The sections by the co-ordinate planes and their focal distances are given below.

The section by the X-Y plane ($z = 0$) is the ellipse

$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1$ with semi-axes a and b and focal distance

$$f = \sqrt{a^2 - b^2} = \sqrt{a_1 - a_2}$$

The section by the Z-X plane ($y = 0$) is the ellipse

$\frac{x^2}{a^2} + \frac{z^2}{c^2} = 1$ with semi-axes a and c and focal distance

$$f = \sqrt{a^2 - c^2} = \sqrt{a_1 - a_3}$$

The section by the Y-X plane ($x = 0$) is the ellipse

$\frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$ with semi-axes b and c and focal distance

$$f = \sqrt{b^2 - c^2} = \sqrt{a_2 - a_3}$$

If in equation (**8**) we let $a = b$ the sections by the planes parallel to the X-Y plane will be circles whose centres lie along the Z axis and the surface is cut out by revolving the ellipse

$$\frac{x^2}{a^2} + \frac{z^2}{c^2} = 1$$

about the Z axis. If a is the major axis and c the minor axis of this ellipse as has been assumed and stated in the assumption

Digitized by Google

$a > c$, then the figure is cut out by revolving an ellipse about its minor axis. Such a figure is called an oblate spheroid. If the rotation occurs around the major axis the figure is called a prolade spheroid.

If $a = b = c$ the ellipsoid reduces to a sphere.

The form of the oblate spheroid is shown in Fig. 5.

Confocal Quadric Surfaces

In all three cases investigated above it will be observed that the squares of the focal distances of the principal sections (sections cut out on the X-Y, Y-Z, Z-X planes) are the square roots of the differences of the three constants a_1, a_2 and a_3. Therefore, if we add a constant to each of the three constants a_1, a_2 and a_3 we obtain a surface whose principal sections have

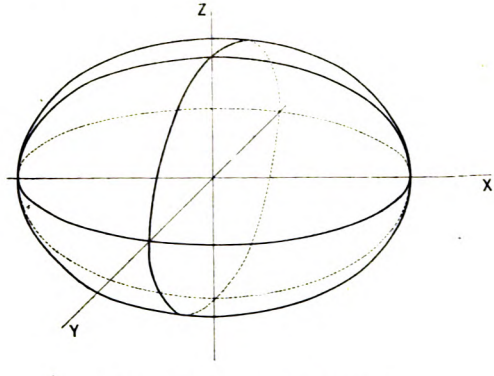


Fig. 5—Oblate Spheroid
Axis of revolution about Z axis.

the same foci as before or what is called a surface confocal with respect to the original.

For example, if we take the equation of an ellipsoid

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1 \qquad (9)$$

the focal distance of the principal section made by the X-Y plane has been seen to be

$$f = \sqrt{a^2 - b^2} = \sqrt{a_1 - a_2}$$

If we now add the constant quantity ρ to a_1 and a_2 we have as the focal distance of this principal section.

$$\sqrt{(a_1 - \rho) - (a_2 - \rho)} = \sqrt{a_1 - \rho - a_2 + \rho} = \sqrt{a_1 - a_2}$$

Digitized by Google

and thus the focal distance has remained the same. Similarly for the other principal sections, and we therefore see that

$$\frac{x^2}{a^2+\rho}+\frac{y^2}{b^2+\rho}+\frac{z^2}{c^2+\rho}=1 \tag{10}$$

represents a surface confocal with the original for any real value positive or negative of ρ.

If as we have assumed throughout a is greater than b and b is greater than c or,

$$a > b > c$$

then the character of the surface represented by equation (**10**) will be seen to be determined as follows:

(1) If $\rho > -c^2$ the surface is an ellipsoid.
(2) If $-c^2 > \rho > -b^2$ the surface is a hyperboloid of one sheet.
(3) If $-b^2 > \rho > -a^2$ the surface is a hyperboloid of two sheets.
(4) If $-a^2 > \rho$ the surface is imaginary.

Suppose we now wish to pass through a given point in space x, y, z a quadric surface confocal with the ellipsoid

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}+\frac{z^2}{c^2}=1 \tag{11}$$

Where $$a > b > c.$$

We have seen that its equation will be

$$\frac{x^2}{a^2+\rho}+\frac{y^2}{b^2+\rho}+\frac{z^2}{c^2+\rho}=1 \tag{12}$$

from which the value of ρ can be determined when the values of x, y, z of the desired point are given.

It will be seen that this equation (**12**) is a cubic equation in ρ and therefore will have three roots say ρ_1, ρ_2, ρ_3 and if it is found that these roots are all real there will be three confocal surfaces which will pass through any desired point x, y, z in space. Since an equation of odd degree always has at least one real root we see that the other two roots will be real or both imaginary since imaginary roots always enter an equation in pairs.

Digitized by Google

In order to investigate the roots of our equation (**12**) we can write it when cleared of fractions as follows:

$$(a^2+\rho)(b^2+\rho)(c^2+\rho)-x^2(b^2+\rho)(c^2+\rho)-y^2(a^2+\rho)(c^2+\rho) - z^2(a^2+\rho)(b^2+\rho)=f(\rho)=0 \quad (\mathbf{13})$$

This is our cubic equation in ρ and a, b, c, x, y, z are the constants.

We have just seen that the character of the confocal surface depends upon the magnitude of ρ with respect to the three constants a, b and c. To recapitulate

(1) If $\rho > -c^2$ the surface is an ellipsoid.
(2) If $-c^2 > \rho > -b^2$ the surface is a hyperboloid of one sheet.
(3) If $-b^2 > \rho > -a^2$ the surface is a hyperboloid of two sheets.
(4) If $-a^2 > \rho$ the surface is imaginary.

We will now substitute for ρ in equation (**13**) the values

(1) $\rho = +\infty$
(2) $\rho = -c^2$
(3) $\rho = -b^2$
(4) $\rho = -a^2$

which will be seen to be the extreme values as outlined above. It should be observed that $\rho = -\infty$ would result in an imaginary surface and therefore is not considered.

Upon making these substitutions for ρ in equation (**13**) and remembering that $a > b > c$ we will obtain the following as regards to changes of sign of our cubic equation in ρ which is represented for brevity by $f(\rho)$.

When $\rho = +\infty$
sign $f(\rho) = +\infty$

and it is observed that $f(\rho)$ is a positive quantity for all values of x, y, z, a, b, c constant under the assumed relation $a > b > c$.

When $\rho = -c^2$
$f(\rho) = -z^2(a^2-c^2)(b^2-c^2)$
sign $f(\rho) = (-)(+) \qquad (+) = (-)$

in this case we observe that $f(\rho)$ is negative and therefore $f(\rho)$ has changed from a positive value in the previous case to a negative value in this case. Therefore, $f(\rho)$ has passed through zero somewhere between $\rho = +\infty$ and $\rho = -c^2$, that is, there is a real root between these two values. Call this root λ and

Digitized by Google

observe that it occurs in the region which specified that the confocal surface will be an ellipsoid.

When $\rho = -b^2$

$$f(\rho) = -y^2(c^2 - b^2)(a^2 - b^2)$$

sign $f(\rho) = (-)(-) \quad (+) = (+)$

Here again there has been a change in sign and therefore there is another real root somewhere between $\rho = -c^2$ and $\rho = -b^2$. Call this root μ and observe that it occurs in the region which specifies that the confocal surface defined by it will be a hyperboloid of one sheet.

When $\rho = -a^2$

$$f(\rho) = -x^2(b^2 - a^2)(c^2 - a^2)$$

sign $f(\rho) = (-) \quad (-) \quad (-) \quad = (-)$

and we see that there is another change in sign and therefore another real root in the interval between $\rho = -b^2$ and $\rho = -a^2$. Call this root ν and observe that it lies in the interval which specifies that the confocal shall be a hyperboloid of two sheets.

We have thus accounted for the three roots of the cubic and found their general location also that they are all real.[34] Thus we have seen that through any given point in space, say x', y', z' there will pass one surface of each of the three kinds and therefore we may represent the given point in space either by its rectangular co-ordinates x', y', z' or by the three values λ, μ, ν which are the three values of ρ as determined by the cubic equation in

$$\frac{x^2}{a^2 + \rho} + \frac{y^2}{b^2 + \rho} + \frac{z^2}{c^2 + \rho} = 1$$

in which the values of x, y, z are taken as x' y' z'.

If we write for the sake of brevity.

$$F(\lambda, x, y, z) = \frac{x^2}{a^2 + \lambda} + \frac{y^2}{b^2 + \lambda} + \frac{z^2}{c^2 + \lambda} - 1 = 0$$

$$F(\lambda, x, y, z) = 0 \qquad (14)$$

We see that equation (**14**) defines λ as a function of x, y, z which

34. A complete treatment of the cubic equations will be found in "Todhunter's Theory of Equations". Page 109.

Digitized by Google

is a point in space and therefore λ is said to be defined as a point function. Similarly

$$F(\mu, x, y, z) = 0 \tag{15}$$

$$F(\nu, x, y, z) = 0 \tag{16}$$

define μ and ν as point functions.

If we have given the values of λ, μ, ν in these three equations we determine completely the ellipsoid λ = constant, and the hyperboloid of one sheet μ = constant, and the hyperboloid of two sheets ν = constant, and hence their point of intersection x, y, z and its seven symmetrical points in the other quadrants. It can be further shown that the three surfaces defined by

$$\lambda = \text{constant}$$
$$\mu = \text{constant}$$
$$\nu = \text{constant}$$

are mutually perpendicular at every point of intersection.[35] λ, μ and ν are called the *ellipsoidal* or *elliptic co-ordinates* of the point. They form a system of Orthogonal Curvilinear Co-ordinates.[36]

Normal Oblate Spheroidal Co-ordinates

When any two semi-axes of our standard ellipsoid become equal the above described system of curvilinear co-ordinates breaks down. For in that case the equation

$$\frac{x^2}{a^2 + \rho} + \frac{y^2}{b^2 + \rho} + \frac{z^2}{c^2 + \rho} = 1$$

reduces to a quadratic equation in ρ and therefore has only two roots which we may call λ and μ. The surfaces λ = constant and μ = constant are now confocal ellipsoids and hyperboloids of revolution. Obviously a third family of surfaces is required before the position of a point in space can be fixed by their intersection. Such a family of surfaces, orthogonal to the two present families, is supplied by the system of diametral planes through the axis of revolution of the standard spheroid. The two cases in which the standard ellipsoid is a prolate spheroid and an oblate spheroid require separate treatment. We are

35. A good discussion will be found in "Solid Geometry", Charles Smith, Macmillan and Co., Page 147.

36. The above discussion has mainly been taken from A. G. Webster, "Electricity and Magnetism", pages 27-31.

Digitized by Google

here principally interested in the later case which will now be described.

Let us assume as the standard oblate spheroid

$$\frac{x^2+y^2}{a^2}+\frac{z^2}{c^2}=1 \tag{17}$$

where $a > c$ that is, we have taken the case where the figure is rotated about the z axis.

The equation of the confocal family of surfaces is then

$$\frac{x^2+y^2}{a^2+\rho}+\frac{z^2}{c^2+\rho}=1 \tag{18}$$

which is seen to be a quadratic ρ regarding x, y, z, a, c as constants.

As we have seen before the character of the surface will depend upon the magnitude of ρ with respect to the constants a and c. Remembering $a > c$

(1) If $\rho > -c^2$ the surface is an oblate spheroid.
(2) If $-c^2 > \rho > -a^2$ the surface is a hyperboloid of revolution of one sheet.
(3) If $-a^2 > \rho$ the surface is imaginary.

In order to investigate the roots of (18) we may write it

$$(a^2+\rho)(c^2+\rho)-(x^2+y^2)(c^2+\rho)-z^2(a^2+\rho)=f(\rho)=0 \tag{19}$$

and observe the changes of sign when the following values are substituted for ρ in equation (19).

(1) $\rho = +\infty$
(2) $\rho = -c^2$
(3) $\rho = -a^2$

When $\rho = +\infty$
sign $f(\rho) = +\infty$

and it is observed that $f(\rho)$ is a positive quantity for all values of x, y, z, a, c consistent with the assumed relation $a > c$.

When $\rho = -c^2$
$f(\rho) = -z^2(a^2-c^2)$
sign $f(\rho) = (-) \quad (+) \quad = (-)$

Digitized by Google

in this case we see that $f(\rho)$ is negative and has therefore changed from a positive value in the previous case to a negative value in this case. Therefore, $f(\rho)$ has passed through zero somewhere between $\rho = +\infty$ and $\rho = -c^2$, that is, there is a real root between these two values. Call this root λ and observe that it occurs in the region which specifies that the confocal surface will be an oblate spheroid.

When $\rho = -a^2$

$$f(\rho) = -(x^2 + y^2)(c^2 - a^2)$$

sign $f(\rho) = (-) \quad (+) \quad (-) \quad = (+)$

Here again there has been a change in sign and therefore there is another real root somewhere between $\rho = -c^2$ and $\rho = -a^2$ Call this root μ and observe that it is in the region which specifies that the confocal surface will be an hyperboloid of revolution of one sheet. We have thus accounted for the two roots of our quadratic and also found their approximate location; also that they are real.

We may now write

$$F(\lambda, x, y, z) = \frac{x^2 + y^2}{a^2 + \lambda} + \frac{z^2}{c^2 + \lambda} - 1 = 0$$

or,

$$F(\lambda, x, y, z) = 0 \tag{20}$$

Similarly,

$$F(\mu, x, y, z) = 0 \tag{21}$$

Now, as we have seen before, in order to determine completely a point in space we must have another equation which defines a surface which will intersect the two present surfaces $\lambda =$ constant, and, $\mu =$ constant, at all real points. As has already been said such a system of surfaces is that of the diametral planes through the axis of revolution of our standard oblate spheroid.

In this case, we have taken the z-axis as the axis of revolution. We, therefore, wish the equation of the plane which passes through the intersection of the planes $x = 0$ and $y = 0$. The equation of this plane may be written.[37]

$$y - \nu x = 0$$

where ν may have any value.

37. See—Charles Smith "Solid Geometry," Macmillan and Co., page 11.

Digitized by Google

Thus we may write

$$F(\nu, x, y, z) = y - \nu x = 0 \qquad (22)$$

If we are given the values of λ, μ, ν these three equations determine completely the oblate spheroid, λ = constant, the hyperboloid of revolution of one sheet, μ = constant, and the diametral plane through the axis of revolution, ν = constant. Hence their point of intersection x, y, z and its seven symmetrical points in the other quadrants is completely determined. It can further be shown that the three surfaces defined by

$$\lambda = \text{constant}$$
$$\mu = \text{constant}$$
$$\nu = \text{constant}$$

are mutually perpendicular at every point of intersection. We may thus take λ, μ, ν as a set of normal curvilinear co-ordinates.

In order to simplify the work which will follow we will make certain simplifications in the form of the equations of the three surfaces, the intersection of which represent our three co-ordinates of a point. Rewriting equations (**20**), (**21**), (**22**) of the three orthogonal surfaces,

$$F(\lambda, x, y, z) = \frac{x^2}{a^2 + \lambda} + \frac{y^2}{a^2 + \lambda} + \frac{z^2}{c^2 + \lambda} - 1 = 0 \qquad (23)$$

$$F(\mu, x, y, z) = \frac{x^2}{a^2 + \mu} + \frac{y^2}{a^2 + \mu} + \frac{z^2}{c^2 + \mu} - 1 = 0 \qquad (24)$$

$$F(\nu, x, y, z) = y - \nu x = 0 \qquad (25)$$

Where

$$a > c$$
$$\lambda > -c^2$$
$$-c^2 > \mu > -a^2$$

ν may have any real value positive or negative.

Let us now make the following substitutions in equations (**23**) and (**24**).

Let

$$a^2 - c^2 = E^2 \qquad (26)$$

and

$$a^2 + \lambda = E^2 D \qquad (27)$$

Digitized by Google

subtracting we obtain

$$c^2 + \lambda = E^2 (D - 1) \tag{28}$$

also let

$$a^2 + \mu = E^2 F \tag{29}$$

subtracting (**26**) from (**29**) we obtain

$$c^2 + \mu = E^2 (F - 1) \tag{30}$$

If we now substitute (**27**) and (**28**) in (**23**), and (**29**) and (**30**) in (**24**) we have

$$\frac{x^2}{E^2 D} + \frac{y^2}{E^2 D} + \frac{z^2}{E^2 (D - 1)} - 1 = 0 \tag{31}$$

$$\frac{x^2}{E^2 F} + \frac{y^2}{E^2 F} + \frac{z^2}{E^2 (F - 1)} - 1 = 0 \tag{32}$$

We may now make the further substitutions,

Putting

$$E^2 = c'^2$$
$$E^2 D = \lambda'^2$$
$$E^2 F = \mu'^2$$

We then may write (**31**) and (**32**)

$$\frac{x^2}{\lambda'^2} + \frac{y^2}{\lambda'^2} + \frac{z^2}{\lambda'^2 - c'^2} - 1 = 0 \tag{33}$$

$$\frac{x^2}{\mu'^2} + \frac{y^2}{\mu'^2} + \frac{z^2}{\mu'^2 - c'^2} - 1 = 0 \tag{34}$$

If in these equations λ'^2 is greater than c'^2 and c'^2 is greater than μ'^2, that is

$$\lambda'^2 > c'^2 > \mu'^2$$

then equation (**33**) is the equation of a confocal family of oblate spheroids in a simplified form and equation (**34**) the confocal family of hyperboloids of revolution. The Z-axis is the axis of revolution and $2c'$ is the focal distance. In other words, if we take an ellipse and a hyperbola having the same foci (focal distance $2c'$) and revolve them about the minor axis of the ellipse (in this case the z-axis) we shall get a pair of surfaces

Digitized by Google

which are mutually perpendicular; also a plane through the axis of revolution will cut both the spheroid and hyperboloid orthogonally. We may now drop the primes and write the equations of the three surfaces:

$$F_1(x, y, z, \lambda) = \frac{x^2}{\lambda^2} + \frac{y^2}{\lambda^2} + \frac{z^2}{\lambda^2 - c^2} - 1 = 0 \qquad (35)$$

$$F_2(x, y, z, \mu) = \frac{x^2}{\mu^2} + \frac{y^2}{\mu^2} + \frac{z^2}{\mu^2 - c^2} - 1 = 0 \qquad (36)$$

$$F_3(x, y, z, \nu) = y - \nu x = 0 \qquad (37)$$

where $\lambda^2 > c^2 > \mu^2$, $2c$ being the distance between foci.

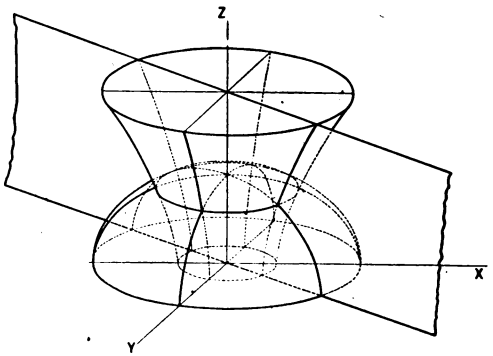


FIG. 6—INTERSECTION OF AN OBLATE SPHEROID, CONFOCAL HYPERBOLOID AND A PLANE THROUGH THE AXIS OF ROTATION

For all values of λ, μ and ν consistent with the inequality written above the surfaces (**35**), (**36**) and (**37**) intersect in real points and cut orthogonally. We can, therefore, represent any given point in space say x, y, z by the intersection of the three surfaces provided we assign the proper values to λ, μ and ν. Therefore, λ, μ and ν are a set of orthogonal curvilinear co-ordinates.

The form of the three surfaces is shown in Fig. 6.

LAPLACE'S EQUATION IN NORMAL OBLATE SPHEROIDAL CO-ORDINATES

If we solve equations (**35**), (**36**) and (**37**) simultaneously we will obtain the values of x, y and z in terms of our co-ordinates λ, μ and ν.

Digitized by Google

To do this we may divide equation (**35**) through by μ^2 and equation (**36**) through by λ^2 and then subtract. We obtain upon simplification.

$$z^2 = \frac{(\lambda^2 - c^2)(c^2 - \mu^2)}{c^2} \tag{38}$$

Substituting this value of z^2 in equation (**35**) we obtain

$$x^2 + y^2 = \frac{\lambda^2 \mu^2}{c^2}$$

and upon substituting the value of y from equation (**37**) we obtain

$$x^2 = \frac{\lambda^2 \mu^2}{c^2 (1 + \nu^2)} \tag{39}$$

similarly we obtain

$$y^2 = \frac{\lambda^2 \mu^2 \nu^2}{c^2 (1 + \nu^2)} \tag{40}$$

Equations (**38**), (**39**) and (**40**) enable us to express the position of a point in space x, y, z when the values of λ, μ and ν are given.

Let $x = x_0$, $y = y_0$, $z = z_0$ be the rectangular co-ordinates of the point in space determined by the intersection of the three surfaces $\lambda = \lambda_0$, $\mu = \mu_0$, $\nu = \nu_0$.

The rectangular co-ordinates of the point

$$\lambda = \lambda_0 + d\lambda$$
$$\mu = \mu_0$$
$$\nu = \nu_0$$

will be

$$x = x_0 + \frac{\partial x}{\partial \lambda} d\lambda$$

$$y = y_0 + \frac{\partial y}{\partial \lambda} d\lambda$$

$$z = z_0 + \frac{\partial z}{\partial \lambda} d\lambda$$

Digitized by Google

That is, it will be the original position plus the rate of change of x with respect to a change in λ multiplied by the increment in λ. This will be readily seen from Fig. 7.

The square of the distance between the points λ_0 and $\lambda_0 + d\lambda$ will be

$$dn_1^2 = \left(\frac{\partial x}{\partial \lambda}\right)^2 d\lambda^2 + \left(\frac{\partial y}{\partial \lambda}\right)^2 d\lambda^2 + \left(\frac{\partial z}{\partial \lambda}\right)^2 d\lambda^2$$

$$dn_1^2 = \left[\left(\frac{\partial x}{\partial \lambda}\right)^2 + \left(\frac{\partial y}{\partial \lambda}\right)^2 + \left(\frac{\partial z}{\partial \lambda}\right)^2\right] d\lambda^2 \qquad (41)$$

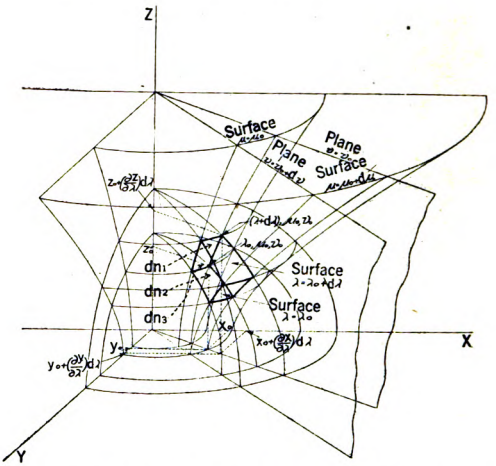


FIG. 7—ELEMENTARY SOLID CUT OUT BY THE INTERSECTION OF A PAIR OF CONFOCAL HYPERBOLOIDS OF REVOLUTION, A PAIR OF ELLIPSOIDS OF REVOLUTION AND A PAIR OF PLANES THROUGH THE AXIS OF REVOLUTION (Z AXIS)

In the limit the elementary curvilinear rectangular parallelopiped is simply a rectangular parallelopiped, that is, the effect of the curvative will introduce an effect which will be an infinitesimal of higher order than $d\lambda$ and dn_1 and, therefore, may be neglected. From this consideration it will be observed that dn_1 is the differential unit of length normal to the surface $\lambda = \lambda_0$. Thus, a considerable simplification has resulted from the fact that our system of curvilinear co-ordinates are orthogonal.

In like manner, we can write down the expressions for the differential unit normals to the other two surfaces

$\mu = \mu_0$ and $\nu = \nu_0$.

Digitized by Google

Thus,

$$dn_2^2 = \left[\left(\frac{\partial x}{\partial \mu}\right)^2 + \left(\frac{\partial y}{\partial \mu}\right)^2 + \left(\frac{\partial z}{\partial \mu}\right)^2\right] d\mu^2 \tag{42}$$

which is the elementary normal to the surface $\mu = \mu_0$
Similarly

$$dn_3^2 = \left[\left(\frac{\partial x}{\partial \nu}\right)^2 + \left(\frac{\partial y}{\partial \nu}\right)^2 + \left(\frac{\partial z}{\partial \nu}\right)^2\right] d\nu^2 \tag{43}$$

is the elementary normal to the surface $\nu = \nu_0$

If we now let

$$\frac{1}{h_1^2} = \left(\frac{\partial x}{\partial \lambda}\right)^2 + \left(\frac{\partial y}{\partial \lambda}\right)^2 + \left(\frac{\partial z}{\partial \lambda}\right)^2 \tag{44}$$

$$\frac{1}{h_2^2} = \left(\frac{\partial x}{\partial \mu}\right)^2 + \left(\frac{\partial y}{\partial \mu}\right)^2 + \left(\frac{\partial z}{\partial \mu}\right)^2 \tag{45}$$

$$\frac{1}{h_3^2} = \left(\frac{\partial x}{\partial \nu}\right)^2 + \left(\frac{\partial y}{\partial \nu}\right)^2 + \left(\frac{\partial z}{\partial \nu}\right)^2 \tag{46}$$

we can write the three equations for the differential normals in the more compact form.

$$dn_1 = \frac{d\lambda}{h_1} \tag{47}$$

$$dn_2 = \frac{d\mu}{h_2} \tag{48}$$

$$dn_3 = \frac{d\nu}{h_3} \tag{49}$$

The elementary surfaces which form the sides of the differential volume may now be written (see Fig. 7)

$$dS_1 = dn_2\, dn_3 = \left(\frac{d\mu\, d\nu}{h_2 h_3}\right) \tag{50}$$

Digitized by Google

for the surface $\lambda = \lambda_0$

$$d S_2 = dn_1\, dn_3 = \frac{d\lambda\, d\nu}{h_1 h_3} \tag{51}$$

for the surface $\mu = \mu_0$

$$d S_3 = dn_1\, dn_2 = \frac{d\lambda\, d\mu}{h_1 h_2} \tag{52}$$

for the surface $\nu = \nu_0$

We may now write the differential volume $d\nu$ of the rectangular parallelopiped

$$d\nu = dn_1\, dn_2\, dn_3 = \frac{d\lambda\, d\mu\, d\nu}{h_1 h_2 h_3} \tag{53}$$

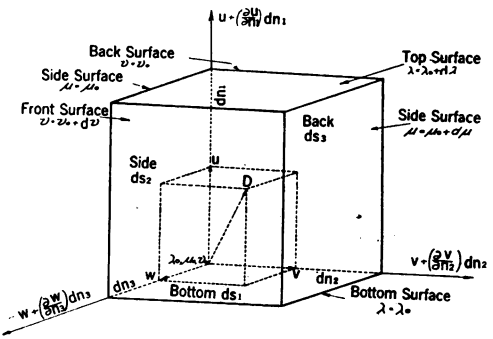


FIG. 8

We can now proceed to write down Laplace's equation in our present system of orthogonal curvilinear co-ordinates. We will here consider the case of a homogeneous and isotropic medium. The clearest method of obtaining Laplace's equation is to apply the well known laws of flow of an incompressible fluid to the infinitesimal unit of volume bounded by the intersection of the six surfaces,

$$\lambda = \lambda_0 \quad \mu = \mu_0 \quad \nu = \nu_0$$
$$\lambda = \lambda_0 + d\lambda_1 \quad \mu = \mu_0 + d\mu_1 \quad \nu = \nu_0 + d\nu$$

Now let (see Fig. 8)

u equal the component of the flow density or flux density,

D, at the point λ_0, μ_0, ν_0, parallel to dn_1

Digitized by Google

Similarly

v = component of D parallel to dn_2.

w = component of D parallel to dn_3.

Now the total amount of flux (or flow) leaving the infinitesimal parallelopiped is the sum of the six amounts leaving it through the six faces; each of these is expressed as; flow density $\times$ surface.

Therefore, they are,

$$-u\,ds_1 + \left(u + \frac{\partial u}{\partial n_1}\,dn_1\right) ds_1$$

$$-v\,ds_2 + \left(v + \frac{\partial v}{\partial n_2}\,dn_2\right) ds_2$$

$$-w\,ds_3 + \left(w + \frac{\partial w}{\partial n_3}\,dn_3\right) ds_3$$

In order to see the exact meaning of these three equations we will put the first one in word form. The first term says that the total flux (or flow) entering the lower surface of the infinitesimal parallelopiped is equal to the component of the flux density in the direction perpendicular to the surface $\times$ the area of the lower surface. Since we desire to express the outward flow we designate this inward flow by the minus sign. The second term expresses the total flux outward through the top surface. For this case the component of the flux density will be the original component plus the rate of increase of the component as we move towards the top of the cube multiplied by the height of the cube. This gives the component of the flux density at the top of the cube and if we multiply this by the area we obtain the total outward flow at the top surface.

Adding these three equations together, and substituting the values of ds_1, ds_2, and ds_3 from equations (**50**), (**51**) and (**52**) we get

$$\left(\frac{\partial u}{\partial n_1} + \frac{\partial v}{\partial n_2} + \frac{\partial w}{\partial n_3}\right) dn_1\,dn_2\,dn_3 \qquad (\mathbf{54})$$

Now for any point in space which is neither a source nor a sink of flux we see that the same quantity of flux must leave as enters

Digitized by Google

any closed surface in order that there may be no accumulation within. Therefore, we may write

$$\left(\frac{\partial u}{\partial n_1} + \frac{\partial v}{\partial n_2} + \frac{\partial w}{\partial n_3}\right) dn_1\, dn_2\, dn_3 = 0 \qquad (55)$$

If we write this equation for a unit of volume, that is, if we divide by dn_1, dn_2, dn_3 we have the familiar "equation of continuity."

$$\frac{\partial u}{\partial n_1} + \frac{\partial v}{\partial n_2} + \frac{\partial w}{\partial n_3} = 0$$

If we now write the Fourier-Ohm law in the following form appropriate to flow problems in space, namely;

$$\left.\begin{aligned} u &= -\frac{1}{\tau}\frac{\partial V}{\partial n_1} \\ v &= -\frac{1}{\tau}\frac{\partial V}{\partial n_2} \\ w &= -\frac{1}{\tau}\frac{\partial}{\partial n_3} \end{aligned}\right\} \qquad (56)$$

In other words these equations state that the flow density in a given direction is equal to the potential gradient in that direction divided by the specific resistance to flow. The minus sign indicating that the potential is decreasing in the direction of the flow. We will here take the specific resistance to be unity and equal in all directions, that is, the material has unit specific resistance and is homogeneous and isotropic.

We may, therefore, rewrite equation (**56**) for this case.

$$\left.\begin{aligned} u &= -\frac{\partial V}{\partial n_1} \\ v &= -\frac{\partial V}{\partial n_2} \\ w &= -\frac{\partial V}{\partial n_3} \end{aligned}\right\} \qquad (57)$$

Digitized by Google

Putting these equations in terms of h_1, h_2, h_3 and λ, μ, and ν as given by equations (**47**), (**48**) and (**49**) we have

$$\left.\begin{aligned} u &= -h_1 \frac{\partial V}{\partial \lambda} \\ v &= -h_2 \frac{\partial V}{\partial \mu} \\ w &= -h_3 \frac{\partial V}{\partial \nu} \end{aligned}\right\} \tag{58}$$

If we now write equation (**54**) in terms of λ, μ, ν and h_1, h_2, h_3, in the same manner we have,

$$\left(h_1 \frac{\partial u}{\partial \lambda} + h_2 \frac{\partial v}{\partial \mu} + h_3 \frac{\partial w}{\partial \nu}\right) \frac{d\lambda\, d\mu\, d\nu}{h_1 h_2 h_3} = 0 \tag{59}$$

If we now substitute the values for u, v, w from equation (**58**) we have

$$-\left[h_1 \frac{\partial}{\partial \lambda}\left(h_1 \frac{\partial V}{\partial \lambda}\right) + h_2 \frac{\partial}{\partial \mu}\left(h_2 \frac{\partial V}{\partial \mu}\right) + h_3 \frac{\partial}{\partial \nu}\left(h_3 \frac{\partial V}{\partial \nu}\right)\right] \frac{d\lambda\, d\mu\, d\nu}{h_1 h_2 h_3} = 0 \tag{60}$$

changing signs and simplifying we get,

$$\left[\frac{1}{h_2 h_3}\frac{\partial}{\partial \lambda}\left(h_1 \frac{\partial V}{\partial \lambda}\right) + \frac{1}{h_1 h_3}\frac{\partial}{\partial \mu}\left(h_2 \frac{\partial V}{\partial \mu}\right) + \frac{1}{h_1 h_2}\frac{\partial}{\partial \nu}\left(h_3 \frac{\partial V}{\partial \nu}\right)\right] d\lambda\, d\mu\, d\nu = 0 \tag{61}$$

Now we may put $\frac{1}{h_2 h_3}$ inside the differential $\frac{\partial}{\partial \lambda}$ since $h_2 h_3$ are not functions of λ; similarly for μ and ν. Thus we may write it

$$\left[\frac{\partial}{\partial \lambda}\left(\frac{h_1}{h_2 h_3}\frac{\partial V}{\partial \lambda}\right) + \frac{\partial}{\partial \mu}\left(\frac{h_2}{h_1 h_3}\frac{\partial V}{\partial \mu}\right) + \frac{\partial}{\partial \nu}\left(\frac{h_3}{h_1 h_2}\frac{\partial V}{\partial \nu}\right)\right] d\lambda\, d\mu\, d\nu = 0 \tag{62}$$

Digitized by Google

Now in order to write the equation per unit volume we must divide through by unit of volume, that is, by equation (**53**) and we get

$$h_1 h_2 h_3 \left[\frac{\partial}{\partial \lambda}\left(\frac{h_1}{h_2 h_3}\frac{\partial V}{\partial \lambda}\right) + \frac{\partial}{\partial \mu}\left(\frac{h_2}{h_1 h_3}\frac{\partial V}{\partial \mu}\right) + \frac{\partial}{\partial \nu}\left(\frac{h_3}{h_1 h_2}\frac{\partial V}{\partial \nu}\right)\right] = 0 \tag{63}$$

which is Laplace's equation in orthogonal curvilinear co-ordinates.

We may now proceed to obtain the values of h_1, h_2 and h_3 for our case of normal oblate spheroidal co-ordinates from equations (**33**), (**39**) and (**40**) when combined with equations (**44**), (**45**) and (**46**).

Thus differentiating equations (**38**), (**39**) and (**40**) with respect to λ we obtain

$$\left.\begin{aligned} \frac{\partial x}{\partial \lambda} &= \frac{\mu}{c\sqrt{1+\nu^2}} \\ \frac{\partial y}{\partial \lambda} &= \frac{\mu\nu}{c\sqrt{1+\nu^2}} \\ \frac{\partial z}{\partial \lambda} &= \frac{\lambda}{c}\sqrt{\frac{c^2-\mu^2}{\lambda^2-c^2}} \end{aligned}\right\} \tag{64}$$

Substituting these values in equation (**44**) we obtain

$$\frac{1}{h_1^2} = \left(\frac{\mu}{c\sqrt{1+\nu^2}}\right)^2 + \left(\frac{\mu\nu}{c\sqrt{1+\nu^2}}\right)^2 + \left(\frac{\lambda}{c}\sqrt{\frac{c^2-\mu^2}{\lambda^2-c^2}}\right)^2$$

Simplifying we get

$$\frac{1}{h_1^2} = \frac{\lambda^2-\mu^2}{\lambda^2-c^2} \tag{65}$$

Digitized by Google

Similarly we obtain

$$\left.\begin{aligned} \frac{\partial x}{\partial \mu} &= \frac{\lambda}{c\sqrt{1+\nu^2}} \\ \frac{\partial y}{\partial \mu} &= \frac{\lambda \nu}{c\sqrt{1+\nu^2}} \\ \frac{\partial z}{\partial \mu} &= -\frac{\mu}{c}\sqrt{\frac{\lambda^2 - c^2}{c^2 - \mu^2}} \end{aligned}\right\} \tag{66}$$

From which

$$\frac{1}{h_2^2} = \frac{\lambda^2 - \mu^2}{c^2 - \mu^2} \tag{67}$$

Again

$$\left.\begin{aligned} \frac{\partial x}{\partial \nu} &= -\frac{\lambda \mu \nu}{c(1+\nu^2)^{3/2}} \\ \frac{\partial y}{\partial \nu} &= \frac{\lambda \mu}{c(1+\nu^2)^{3/2}} \\ \frac{\partial z}{\partial \nu} &= 0 \end{aligned}\right\} \tag{68}$$

and

$$\frac{1}{h_3^2} = \frac{\lambda^2 \mu^2}{c^2 (1+\nu^2)^2} \tag{69}$$

If we now substitute these values of $\frac{1}{h_1}$ $\frac{1}{h_2}$, $\frac{1}{h_3}$, in equation (**63**) we get

$$\frac{\mu}{c(1+\nu^2)\sqrt{c^2-\mu^2}} \frac{\partial}{\partial \lambda}\left[\lambda \sqrt{\lambda^2 - c^2}\, \frac{\partial V}{\partial \lambda}\right] +$$

$$\frac{\lambda}{c(1+\nu^2)\sqrt{\lambda^2-c^2}} \frac{\partial}{\partial \mu}\left[\mu \sqrt{c^2 - \mu^2}\, \frac{\partial V}{\partial \mu}\right] +$$

$$\frac{c(\lambda^2 - \mu^2)}{\lambda \mu \sqrt{(\lambda^2 - c^2)(c^2 - \mu^2)}} \frac{\partial}{\partial \nu}\left[(1+\nu^2)\frac{\partial V}{\partial \nu}\right] = 0 \tag{70}$$

Digitized by Google

which is Laplace's equation in our spheroidal coordinates λ, μ and ν.

If now in place of λ, μ and ν we can find some function of λ, some function of μ, and some function of ν which, therefore, will represent the same set of orthogonal surfaces, and if we can choose these functions which we shall designate by α, β and γ, which of course are also functions of x, y and z, so that they are solutions of Laplace's equation when expressed in rectangular co-ordinates, and, therefore, satisfy it when substituted therein. That is, we would have,

$$\left.\begin{aligned} \frac{\partial^2 \alpha}{\partial x^2} + \frac{\partial^2 \alpha}{\partial y^2} + \frac{\partial^2 \alpha}{\partial z^2} &= 0 \\ \frac{\partial^2 \beta}{\partial x^2} + \frac{\partial^2 \beta}{\partial y^2} + \frac{\partial^2 \beta}{\partial z^2} &= 0 \\ \frac{\partial^2 \gamma}{\partial x^2} + \frac{\partial^2 \gamma}{\partial y^2} + \frac{\partial^2 \gamma}{\partial z^2} &= 0 \end{aligned}\right\}$$

under these circumstances equation (**70**) will be reduced to a more simple and symmetrical form. It must be remembered that the existence of these functions α, β, γ, is merely tentative. The criterion for their existence will be given later.

Equation (**70**) is Laplace's equation expressed in terms of λ, μ and ν.

Assuming now that in equation (**70**) V is a function of λ only; in that case

$$\frac{\partial V}{\partial \mu} = 0 \text{ and } \frac{\partial V}{\partial \nu} = 0$$

and equation (**70**) would then reduce to

$$\frac{\partial}{\partial \lambda}\left[\lambda \sqrt{\lambda^2 - c^2}\, \frac{\partial V}{\partial \nu}\right] = 0 \qquad (71)$$

Integrating with respect to λ we get

$$\lambda \sqrt{\lambda^2 - c^2}\, \frac{dV}{d\lambda} = c_1 \qquad (72)$$

Digitized by Google

whence

$$dV = \frac{c_1 \, d\lambda}{\lambda \sqrt{\lambda^2 - c^2}} \tag{73}$$

and integrating again

$$V = \frac{c_1}{c} \sec^{-1} \frac{\lambda}{c} + K_1 \tag{74}$$

Here V is a function of λ which satisfies Laplace's equation. Call this value of V which, is a function of λ and which satisfies Laplace's equation, α leaving the constant c_1 undertermined thus

$$d\alpha = \frac{c_1 \, d\lambda}{\lambda \sqrt{\lambda^2 - c^2}} \tag{75}$$

and

$$\alpha = \frac{c_1}{c} \sec^{-1} \frac{\lambda}{c} + K_1 \tag{76}$$

The constant K_1 is zero since,

$$\alpha = 0$$

when $\lambda = c$

and $\sec^{-1} 1 = 0$

As above assumed now that V in equation (**70**) is a function of μ only; in this case $\frac{\partial V}{\partial \lambda} = 0$ and $\frac{\partial V}{\partial \nu} = 0$ and

$$\frac{\partial}{\partial \mu} \left[\mu \sqrt{c^2 - \mu^2} \frac{\partial V}{\partial \mu} \right] = 0 \tag{77}$$

Integrating

$$\mu \sqrt{c^2 - \mu^2} \frac{dV}{d\mu} = c_2 \tag{78}$$

$$dV = \frac{c_2 \, d\mu}{\mu \sqrt{c^2 - \mu^2}} \tag{79}$$

$$V = -\frac{c_2}{c} \operatorname{sech}^{-1} \frac{\mu}{c} + K_2 \tag{80}$$

Digitized by Google

Call this value of V which is a function of μ only, and which satisfies Laplace's equation, β, leaving the constant c_2 undetermined we have

$$d\beta = \frac{c_2\, d\mu}{\mu\sqrt{c^2-\mu^2}} \tag{81}$$

$$\beta = -\frac{c_2}{c}\operatorname{sech}^{-1}\frac{\mu}{c} + K_2 \tag{82}$$

The constant of integrating K_2 is zero since

$$\beta = 0$$

when $\mu = c$

and $\operatorname{sech}^{-1}1 = 0$

Similarly

$$\frac{\partial}{\partial\nu}\left[(1+\nu^2)\frac{\partial V}{\partial\nu}\right] = 0 \tag{83}$$

$$(1+\nu^2)\frac{dV}{d\nu} = c_3 \tag{84}$$

$$dV = \frac{c_3\, d\nu}{1+\nu^2} \tag{85}$$

$$V = c_3\tan^{-1}\nu + K_3 \tag{86}$$

If, as before, we call this value of V, which is a function of ν only and which satisfies Laplace's equation, γ, leaving the constant c_3 undetermined we have

$$d\gamma = \frac{c_3\, d\nu}{1+\nu^2} \tag{87}$$

$$\gamma = c_3\tan^{-1}\nu + K_3 \tag{88}$$

The constant of integration K_3 vanishes since

$$\gamma = 0$$

when $\nu = 0$

and $\tan^{-1}0 = 0$

Digitized by Google

If we now substitute these values in equation (**70**) we can express Laplace's equation in terms of our new functions α, β and γ and thereby obtain a simpler equation. To do this let us take equation (**70**) term by term.
The first term is

$$\frac{\mu}{c(1+\nu^2)\sqrt{c^2-\mu^2}}\frac{\partial}{\partial\lambda}\left[\lambda\sqrt{\lambda^2-c^2}\,\frac{\partial V}{\partial\lambda}\right]$$

expanding the indicated differentiation we get

$$\frac{\mu}{c(1+\nu^2)\sqrt{c^2-\mu^2}}\left[\frac{\partial}{\partial\lambda}\left(\lambda\sqrt{\lambda^2-c^2}\,\frac{\partial V}{\partial\lambda}+\lambda\sqrt{\lambda^2-c^2}\,\frac{\partial^2 V}{\partial\lambda^2}\right)\right] \qquad (89)$$

From equation (**71**) the first term within the bracket is equal to zero.

If we now assign the following values to the constants, c_1, c_2 and c_3

$$c_1 = -c_2 = c \text{ and } c_3 = 1$$

We have from equation (**73**)

$$\frac{dV}{d\lambda} = \frac{c}{\lambda\sqrt{\lambda^2-c^2}}$$

$$\frac{d^2V}{d\lambda^2} = \frac{d}{d\lambda}\left(\frac{c}{\lambda\sqrt{\lambda^2-c^2}}\right)$$

$$\frac{d^2V}{d\lambda^2} = \frac{-c[(\lambda^2-c^2)+\lambda^2]}{\lambda^2(\lambda^2-c^2)\sqrt{\lambda^2-c^2}} \qquad (90)$$

Now from equation (**75**) we have

$$\frac{d\lambda}{d\alpha} = \frac{\lambda\sqrt{\lambda^2-c^2}}{c}$$

$$\left(\frac{d\lambda}{d\alpha}\right)^2 = \frac{\lambda^2(\lambda^2-c^2)}{c^2} \qquad (91)$$

Digitized by Google

Combining (**90**) and (**91**) we obtain

$$\frac{d^2\ V}{d\ \alpha^2} = \frac{d^2\ V}{d\ \lambda^2}\frac{d\ \lambda^2}{d\ \alpha^2} = -\frac{(\lambda^2 - c^2) + \lambda^2}{c\ \sqrt{\lambda^2 - c^2}} \tag{92}$$

Now comparing (**90**) and (**92**) it will be seen that

$$\frac{d^2\ V}{d\ \lambda^2} = \frac{c^2}{\lambda^2\ (\lambda^2 - c^2)}\frac{d^2\ V}{d\ \alpha^2} \tag{93}$$

If we now substitute this value of $\frac{d^2\ V}{d\ \lambda^2}$ in the second term of equation (**89**) we get

$$\frac{\mu}{c\ (1 + \nu^2)\ \sqrt{c^2 - \mu^2}}\ \left\{\lambda\ \sqrt{\lambda^2 - c^2}\ \left[\frac{c^2}{\lambda^2\ (\lambda^2 - c^2)}\frac{\partial^2\ V}{\partial\ \alpha^2}\right]\right\}$$

or simplifying the first term of equation (**70**) when expressed in terms of $\frac{\partial^2\ V}{\partial\ \alpha^2}$ we get

$$\frac{c}{\lambda\ (1 + \nu^2)\ \sqrt{c^2 - \mu^2}\ \sqrt{\lambda^2 - c^2}}\frac{\partial^2\ V}{\partial\ \alpha^2} \tag{94}$$

If we now perform the same operation upon the second term of equation (**70**) which is

$$\frac{\lambda}{c\ (1 + \nu^2)\ \sqrt{\lambda^2 - c^2}}\frac{\partial}{\partial\ \mu}\left[\mu\ \sqrt{c^2 - \mu^2}\ \frac{\partial\ V}{\partial\ \mu}\right] \tag{95}$$

expanding the indicated differentiation we have

$$\frac{\lambda}{c\ (1 + \nu^2)\ \sqrt{\lambda^2 - c^2}}\ \left[\frac{\partial}{\partial\ \mu}\left(\mu\ \sqrt{c^2 - \mu^2}\right)\frac{\partial\ V}{\partial\ \mu} + \mu\ \sqrt{c^2 - \mu^2}\frac{\partial^2\ V}{\partial\ \mu^2}\right] \tag{96}$$

Digitized by Google

Equation (**77**) tells us that the first term within the bracket is zero.

Now from equation (**79**) putting $c_2 = -c$ we have

$$\frac{d\,V}{d\,\mu} = \frac{-c}{\mu\,\sqrt{c^2-\mu^2}}$$

and then

$$\frac{d^2\,V}{d\,\mu^2} = \frac{c\,[\,(c^2-\mu^2)-\mu^2]}{\mu^2\,(c^2-\mu^2)\,\sqrt{c^2-\mu^2}} \tag{97}$$

From equation (**81**) we have

$$\frac{d\,\mu}{d\,\beta} = \frac{\mu\,\sqrt{c^2-\mu^2}}{-c}$$

$$\frac{d\,\mu^2}{d\,\beta^2} = \frac{\mu^2(c^2-\mu^2)}{c^2} \tag{98}$$

From (**97**) and (**98**) we obtain

$$\frac{d^2\,V}{d\,\beta^2} = \frac{d^2\,V}{d\,\mu^2}\frac{d\,\mu^2}{d\,\beta^2} = \frac{(c^2-\mu^2)-\mu^2}{c\,\sqrt{c^2-\mu^2}} \tag{99}$$

Now from (**97**) and (**99**) it will be seen that the following relation exists

$$\frac{d^2\,V}{d\,\mu^2} = \frac{c^2}{\mu^2\,(c^2-\mu^2)}\frac{d^2\,V}{d\,\beta^2} \tag{100}$$

Hence substituting this value in equation (**96**) we get for the second term of equation (**70**) when expressed in terms of $\frac{\partial^2 V}{\partial\,\beta^2}$ the following.

$$\frac{\lambda\,c}{\mu\,(1+\nu^2)\,\sqrt{c^2-\mu^2}\,\sqrt{\lambda^2-c^2}}\frac{\partial^2\,V}{\partial\,\beta^2} \tag{101}$$

Now as before expand the third term of equation (**70**)

$$\frac{c\,(\lambda^2-\mu^2)}{\lambda\,\mu\,\sqrt{\lambda^2-c^2}\,\sqrt{c^2-\mu^2}}\left[\frac{\partial}{\partial\,\nu}(1+\nu^2)\,\frac{\partial\,V}{\partial\,\nu} + (1+\nu^2)\,\frac{\partial^2\,V}{\partial\,\nu^2}\right] \tag{102}$$

Digitized by Google

and observe that the first term within the brackets vanishes by equation (**83**).

Now from equation (**85**) putting $c_3 = 1$, we get,

$$\frac{d\,V}{d\,\nu} = \frac{1}{1+\nu^2}$$

$$\frac{d^2\,V}{d\,\nu^2} = \frac{-\,2\,\nu}{(1+\nu^2)^2} \qquad (\mathbf{103})$$

From equation (**87**)

$$\frac{d\,\nu}{d\,\gamma} = 1 + \nu^2$$

$$\frac{d\,\nu^2}{d\,\gamma^2} = (1+\nu^2)^2 \qquad (\mathbf{104})$$

From (**103**) and (**104**)

$$\frac{d^2\,V}{d\,\gamma^2} = \frac{d^2\,V}{d\,\nu^2}\,\frac{d\,\nu^2}{d\,\gamma^2} = -\,2\,\nu \qquad (\mathbf{105})$$

Now from (**103**) and (**105**) we get

$$\frac{d^2\,V}{d\,\nu^2} = \frac{1}{(1+\nu^2)^2}\,\frac{d^2\,V}{d\,\gamma^2} \qquad (\mathbf{106})$$

Hence substituting this value in equation (**102**) we get for the third term of equation (**70**) when expressed in terms of $\frac{\partial^2 V}{\partial\,\gamma^2}$ the following.

$$\frac{c\,(\lambda^2-\mu^2)}{\lambda\,\mu\,(1+\nu^2)\,\sqrt{c^2-\mu^2}\,\sqrt{\lambda^2-c^2}}\,\frac{\partial^2\,V}{\partial\,\gamma^2} \qquad (\mathbf{107})$$

If we now combine the three terms as given by equations (**94**), (**101**) and (**107**) we get

$$\frac{1}{\lambda^2}\,\frac{\partial^2\,V}{\partial\,\alpha^2} + \frac{1}{\mu^2}\,\frac{\partial^2\,V}{\partial\,\beta^2} + \frac{\lambda^2-\mu^2}{\lambda^2-\mu^2}\,\frac{\partial^2\,V}{\partial\,\gamma^2} = 0 \qquad (\mathbf{108})$$

Digitized by Google

or since from equation (**76**), (**82**) and (**88**) and remembering that we put $c_1 = -c_2 = c_3 = 1$ we have

$$\left.\begin{aligned} \lambda &= c \sec \alpha \\ \mu &= c \operatorname{sech} \beta \\ \nu &= \tan \gamma \end{aligned}\right\} \qquad (109)$$

we can now write equation (**108**)

$$\cos^2 \alpha \frac{\partial^2 V}{\partial \alpha^2} + \cosh^2 \beta \frac{\partial^2 V}{\partial \beta^2} + (\cosh^2 \beta - \cos^2 \alpha) \frac{\partial^2 V}{\partial \gamma^2} = 0 \qquad (110)$$

which is Laplace's equation expressed in terms of what have been called normal oblate spheroidal co-ordinates.

When using this equation (**110**) it is to be noted that the point whose co-ordinates are (α, β, γ) is the point of intersection of an oblate spheroid whose semi-axes are

$c \sec \alpha$ (major axis)
$c \tan \alpha$ (minor axis and the axis of revolution.)

and a hyperboloid of revolution of one sheet whose semi-axes are

$c \operatorname{sech} \beta$ (transverse axis)
$c \tanh \beta$ (conjugate axis, the axis of revolution.)

and a plane containing the axis of revolution of the system and making the angle γ with a fixed plane.

If the axis of revolution is the z axis and the fixed plane of reference is the XZ plane; the rectangular co-ordinates of α, β, γ, will be obtained by substituting the values of λ, μ and ν given by equation (**109**) into equations (**38**), (**39**) and (**40**). This substitution gives

$$\left.\begin{aligned} x &= c \sec \alpha \operatorname{sech} \beta \cos \gamma \\ y &= c \sec \alpha \operatorname{sech} \beta \sin \gamma \\ z &= c \tan \alpha \tanh \beta \end{aligned}\right\} \qquad (111)$$

If now we let α range from 0 to $\frac{\pi}{2}$ β from $-\infty$ to $+\infty$, and γ from 0 to 2π, we shall be able to represent all points in space;

Digitized by Google

and if we agree that negative values of β shall belong to points below a plane through the origin and perpendicular to the axis of revolution and positive values of β to points above that plane. Then not only shall we have no ambiguity, but also the rectangular co-ordinates of any point in space as given by equations (**111**) will have their proper signs. (See Fig. 9)

The above transformation of Laplace's equation, as expressed in terms of the orthogonal curvilinear co-ordinates λ, μ and ν which represent an orthogonal system of surfaces, to the simplified form in which it was expressed in terms of the new co-ordinates α, β, γ was made possible by the assumption that certain functions α, β, γ of λ, μ and ν exist. Thus we determined the value of α by solving equation (**70**) on the assumption that V is a function of λ only; μ and ν not entering. This means that

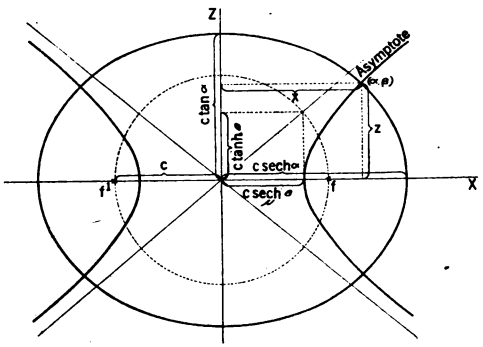


FIG. 9—CONFOCAL ELLIPSE AND HYPERBOLA

we assumed that the curvilinear co-ordinate λ corresponds to a possible equipotential or isothermal surface, for in that case there would be a function of λ which would satisfy Laplace's equation.

We may write it symbolically as follows:

Starting with Laplace's equation in terms of rectangular co-ordinates namely $\Delta^2 V = 0$ and remembering that $\lambda = f(x, y, z)$. Then if it happens that $V = f(\lambda)$ only, is a solution of Laplace's equation, then we may write it

$$V = f(\lambda) = \alpha$$

and upon substituting back in Laplace's equation we would get the condition that

$$\Delta^2 \alpha = 0$$

Digitized by Google

In other words, this means that α as found by this process is a value of the potential V corresponding to such a distribution that the surface obtained by giving particular values to λ are equipotential surfaces. The particular value of the function of λ, α is given in equation (**76**).

The condition that such a function α should exist, for a given system of surfaces, that is, that the distribution described above should be possible will be obtained analytically below.

We have seen that the required condition is merely that V in Laplace's equation may be a function of λ alone.

If V is a function of λ alone and we also remember that λ is a function of x, y and z, we may start from this information to write out Laplace's equation.

We have

$$V = f_1(\lambda)$$

$$\lambda = f_2(x, y, z)$$

Hence

$$\left.\begin{aligned} \frac{\partial V}{\partial x} &= \frac{dV}{d\lambda}\frac{\partial \lambda}{\partial x} \\ \frac{\partial V}{\partial y} &= \frac{dV}{d\lambda}\frac{\partial \lambda}{\partial y} \\ \frac{\partial V}{\partial z} &= \frac{dV}{d\lambda}\frac{\partial \lambda}{\partial z} \end{aligned}\right\}$$

Differentiating again we obtain

$$\left.\begin{aligned} \frac{\partial^2 V}{\partial x^2} &= \frac{d^2V}{d\lambda^2}\frac{\partial \lambda^2}{\partial x^2} + \frac{dV}{d\lambda}\frac{\partial^2 \lambda}{\partial x^2} \\ \frac{\partial^2 V}{\partial y^2} &= \frac{d^2V}{d\lambda^2}\frac{\partial \lambda^2}{\partial y^2} + \frac{dV}{d\lambda}\frac{\partial^2 \lambda}{\partial y^2} \\ \frac{\partial^2 V}{\partial z^2} &= \frac{d^2V}{d\lambda^2}\frac{\partial \lambda^2}{\partial z^2} + \frac{dV}{d\lambda}\frac{\partial^2 \lambda}{\partial z^2} \end{aligned}\right\}$$

Adding these three equations and equating the result to zero in order to obtain Laplace's equation we get

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

Digitized by Google

also

$$\left[\left(\frac{\partial \lambda}{\partial x}\right)^2 + \left(\frac{\partial \lambda}{\partial y}\right)^2 + \left(\frac{\partial \lambda}{\partial z}\right)^2\right]\frac{d^2 V}{d \lambda^2} +$$

$$\left[\frac{\partial^2 \lambda}{\partial x^2} + \frac{\partial^2 \lambda}{\partial y^2} + \frac{\partial^2 \lambda}{\partial z^2}\right]\frac{d V}{d \lambda} = 0$$

We thus have obtained an expression for Laplace's equation based upon the assumption that the potential V shall be a function of λ alone. If we now write it

$$\frac{\frac{\partial^2 \lambda}{\partial x^2} + \frac{\partial^2 \lambda}{\partial y^2} + \frac{\partial^2 \lambda}{\partial z^2}}{\left(\frac{\partial \lambda}{\partial x}\right)^2 + \left(\frac{\partial \lambda}{\partial y}\right)^2 + \left(\frac{\partial \lambda}{\partial z}\right)^2} = -\frac{\frac{d^2 V}{d \lambda^2}}{\frac{d V}{d \lambda}}$$

This may be written in symbolic form

$$\frac{\Delta^2 \lambda}{h_1^2} = F_1(\lambda)$$

where $F_1(\lambda)$ may be any function of λ alone. Thus our required condition is that

$$\frac{\Delta^2 \lambda}{h_1^2} = F_1(\lambda) \qquad (112)$$

and when this is fulfilled the original curvilinear co-ordinate λ corresponds to a possible equipotential or isothermal surface and in this case a function α exists. If similar relations are found to hold for β and γ the reduction of Laplace's equation to the so-called symmetrical form is possible.

Similarly we determine the values of β and γ on the assumption that V is a function of μ only in the case of β and a function of ν only in the case of γ. In that case it is evident that

$\Delta^2 \beta = 0$ and in the second case

$\Delta^2 \gamma = 0$

It is therefore evident that β is a value of V corresponding to such a distribution that the surfaces obtained by giving par-

Digitized by Google

ticular values to μ are equipotential surfaces; and that γ is a value of V corresponding to such a distribution that the surfaces obtained by giving particular value to ν are equipotential surfaces.

From what has been said above it is evident why Lammé, the inventor of this system of co-ordinates called the functions α, β and γ thermometric parameters.[38]

The analytical method of obtaining the criterion for the existence of these functions β and γ is exactly the same as that for the case of α which has been worked out. It is in the case of λ

$$\frac{\Delta^2 \lambda}{h_1^2} = F_1(\lambda)$$

and it is for μ

$$\left.\begin{aligned} \frac{\Delta^2 \mu}{h_2^2} &= F_2(\mu) \\ \text{and for } \nu \qquad \\ \frac{\Delta^2 \nu}{h_3^2} &= F_3(\nu) \end{aligned}\right\} \qquad (113)$$

When these three conditions are fulfilled for λ, μ and ν, the original curvilinear co-ordinates λ, μ and ν correspond to possible equipotential or isothermal surfaces and thermometric parameters α, β and γ exist and the reduction of Laplace's equation to the so-called symmetrical form given by equation (**108**) is possible.

In all of the above work I have followed the development of the subject of orthogonal curvilinear co-ordinates as given in Byerly's Fourier Series and Spherical Harmonics pages 238 to 245 and merely tried to give an unexpurgated description of the process. That is, I have tried to fill in some of the steps in the process which are necessary in order that the average engineer may follow the development with ease.

The solution of the problems given in the following pages is

38. Numerous references to Lamme's work will be found in the following works.

Maxwell, Electricity and Magnetism, page 232; Webster, Electricity and Magnetism, page 22, 64,173; Byerly, Fourier's Series and Spherical Harmonics, page 244, 274; J. H. Jeans, Electricty and Magnetism, page 247; Goursat-Hedrick, Mathematical Analysis, Vol. I, page 80; I. Todhunter, The Functions of Laplace, Lammé and Bessel, page 210.

Digitized by Google

due to Professor W. E. Byerly. I had been struggling with the problem for some time without success and finally took the liberty of writing Professor Byerly concerning my troubles. His reply of January 9th, 1915 to my letter exceeded my expectations for it gave the desired solution as given in the following pages. On February 17th, 1915, I had the further privilege of talking over the problems with him, at which time he cleared up the remaining troublesome points.

Potential at any Point in Space

Laplace's equation (**110**) expressed in the symmetrical form was seen to be

$$\cos^2\alpha\frac{\partial^2 V}{\partial \alpha^2}+\cosh^2\beta\frac{\partial^2 V}{\partial \beta^2}+(\cosh^2\beta-\cos^2\alpha)\frac{\partial^2 V}{\partial \gamma^2}=0 \quad (\mathbf{114})$$

In the present problem we wish to determine the potential at any point in space between two confocal hyperboloids; one of which is chosen to represent the tank with a hole in it; the other representing the rod or connection which passes through the hole in the cover of the tank.

The potential V must satisfy the above equation and is a function of β only. This follows from the fact that the equipotential surfaces will be confocal hyperboloids of revolution.

Therefore, we have,

$$\frac{\partial^2 V}{\partial \alpha^2}=0 \text{ and } \frac{\partial^2 V}{\partial \gamma^2}=0$$

and Laplace's equation reduces in our case to

$$\cosh^2\beta\frac{\partial^2 V}{\partial \beta^2}=0$$

This equation must be true for all values of β and V and since $\cosh^2\beta$ is not zero for all values of β, $\frac{\partial^2 V}{\partial \beta^2}$ must be equal to zero. Thus our equation will be

$$\frac{\partial^2 V}{\partial \beta^2}=0 \quad (\mathbf{115})$$

The solution of this differential equation is seen to be obtained as follows:

Digitized by Google

Integrating,

$$\frac{dV}{d\beta} = A$$

$$dV = A\, d\beta$$

and

$$V = A\ \beta + C \tag{116}$$

which is the solution for the potential at any point in space. The values of the constants of integration A and C will be found from the conditions of the problem.

Thus if $\beta = \beta_0$ for the hyperboloid selected as the tank with hole in it, the potential is

$$V = 0$$

Assuming the tank to be grounded,

Hence $$0 = A\ \beta_0 + C$$

Also when $\beta = \beta_1$ for the hyperboloid selected as the electrode which passes through the hole in the tank

$$V = V_1$$

Hence

$$V_1 = A\ \beta_1 + C$$

Solving these equations simultaneously we have

$$\left.\begin{aligned} C &= \frac{V_1}{1 - \frac{\beta_1}{\beta_0}} \\ A &= \frac{V_1}{\beta_1 - \beta_0} \end{aligned}\right\} \tag{117}$$

Substituting the values of A and C as thus determined into equation (**116**) we have.

$$V = \frac{V_1}{\beta_1 - \beta_0} + \frac{V_1}{1 - \frac{\beta_1}{\beta_0}}$$

or

$$V = \frac{V_1}{\beta_1 - \beta_0}(\beta - \beta_0) \tag{118}$$

which is the complete expression for the potential at any point in space under the assumed terminal conditions.

Digitized by Google

From considerations of symmetry it is obvious that the potential has circular symmetry about the axis of revolution; and, in this case, the z axis has been chosen.

We may now determine the potential at any point in space in rectangular co-ordinates as follows. Suppose we desire the potential at the point x, z for the case in which the semifocal distance is c.

We have for the value of μ which is the semi-transverse axis of the hyperbola

$$\mu = \frac{1}{2}(P F_2 - P F_1)$$

(see Fig. 10)

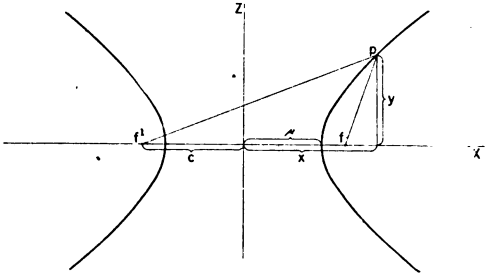


FIG. 10—HYPERBOLA

Hence,

$$\mu = \frac{1}{2}\left[\sqrt{(x+c)^2+z^2} - \sqrt{(x-c)^2+z^2}\right] \qquad (119)$$

Also from equation (**109**) we have,

$$\mu = c \operatorname{sech} \beta$$

$$\cosh \beta = \frac{c}{\mu}$$

$$\beta = \cosh^{-1}\frac{c}{\mu} \qquad (120)$$

Thus we can determine the potential at any point P in space under any desired conditions of c, β_1, β_0, V_1.

Digitized by Google

Potential Distribution of the X-Axis

For this case we have $z = 0$ in equation (**119**) and hence it reduces to

$$\mu = c \tag{121}$$

Now under these conditions μ and x are identical in value for points along the x axis between the origin and the focus. We can, therefore, use equation (**120**) directly without reference to equation (**119**) or (**121**).

Thus we can determine the values of β_1 and β_0 for any value of μ from equation (**120**) or rewriting it here

$$\beta = \cosh^{-1}\frac{c}{\mu} \tag{122}$$

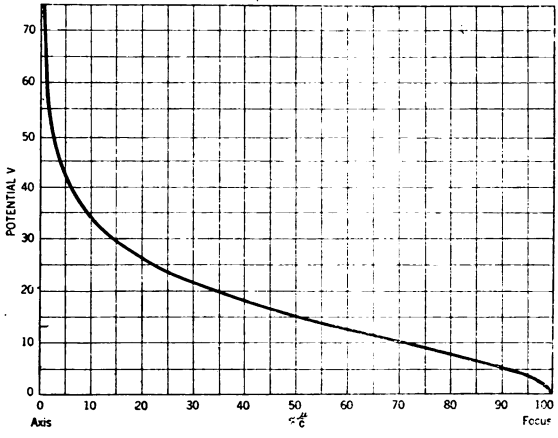


Fig. 11—Calculated Potential Distribution Along the X-Axis

If we select for the hyperboloid β_0 the limiting case that of the infinite plane with a hole in the centre $\beta_0 = 0$ for

$$\beta = \cosh^{-1}\frac{c}{\mu}$$

where $\mu = c$

$$\beta = \beta_0 = \cosh^{-1} 1 = 0$$

We may then write equation (**118**) as follows:—

$$V = \left(\frac{V_1}{\beta_1}\right)\beta \tag{123}$$

Digitized by Google

The potential distribution for this case is shown in the curve, (see Fig. 11). From this curve we may find the proper spacing for the hyperbolas which when rotated about their z axis cut out the equipotential surfaces for unit differences of potential. All we have to do is to divide the potential into equal increments and note the corresponding value of μ or x. In this manner we can construct a diagram similar to Fig. 12. In the case before us the potential has been divided into 51 equal increments.

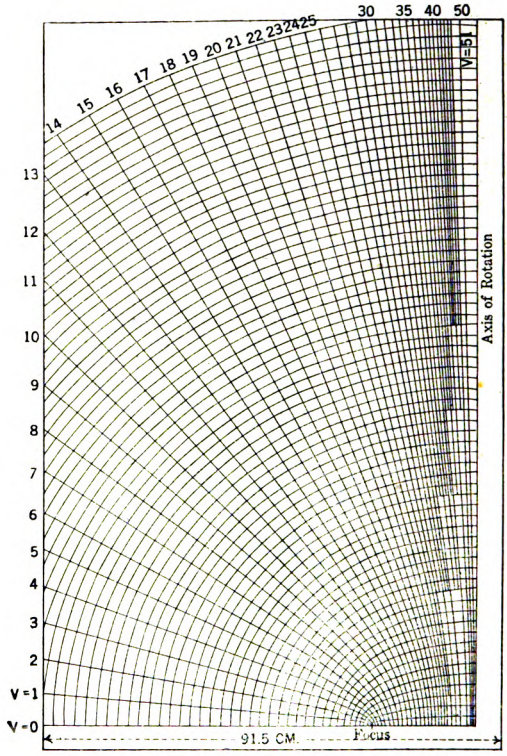


FIG. 12

POTENTIAL GRADIENT AT ANY POINT IN SPACE

The potential gradient is defined as the rate of change of potential in the direction of the greatest decrease in potential, that is, along the normal to the equipotential surface in the direction of decreasing potential. The sign will depend upon whether our unit normal is taken in the direction of increasing or decreasing potential. For the former case the expression for the potential gradient will be positive and for the latter negative. By refer-

Digitized by Google

ence to Figs. 7 and 8 and remembering that we have assumed the tank to be at zero potential it will be seen that we have selected the differential normal $d\,n_2$ in the direction of decreasing potential and, therefore, our expression for the potential gradient will be $-\frac{d\,V}{d\,n_2}$.

We have seen that the potential at any point in space is given by equation (**116**) and is

$$V = A\,\beta + c$$

Thus the potential gradient will be

$$-\frac{d\,V}{d\,n_2} = A\,\frac{d\,\beta}{d\,n_2} \tag{124}$$

where $d\,n_2$ is the normal to the surface $\mu = \mu_0$, (a constant), and in the direction of decreasing potential.

In order to determine β we have the relation

$$\beta = \operatorname{sech}^{-1}\frac{\mu}{c}$$

Hence,

$$\frac{d\,\beta}{d\,\mu} = -\frac{c}{\mu\sqrt{c^2-\mu^2}} \tag{125}$$

Now we have seen from equation (**48**) that

$$d\,n_2 = \frac{d\,\mu}{h_2} \tag{126}$$

Equation (**67**) gives us the value of $\frac{1}{h_2^2}$

$$\frac{1}{h_2^2} = \frac{\lambda^2-\mu^2}{c^2-\mu^2}$$

$$\frac{1}{h_2} = \sqrt{\frac{\lambda^2-\mu^2}{c^2-\mu^2}} \tag{127}$$

Digitized by Google

We may now substitute this value in equation (**126**) and we obtain

$$d n_2 = \sqrt{\frac{\lambda^2 - \mu^2}{c^2 - \mu^2}}\, d\mu \tag{128}$$

Thus,

$$\frac{d\mu}{d n_2} = \sqrt{\frac{c^2 - \mu^2}{\lambda^2 - \mu^2}} \tag{129}$$

Combining now equation (**125**) and (**129**) we have,

$$\frac{d V}{d n_2} = A \frac{d \beta}{d \mu} \frac{d \mu}{d n_2} \tag{130}$$

or,

$$\frac{d V}{d n_2} = - \frac{A C}{\mu \sqrt{c^2 - \mu^2}} \sqrt{\frac{c^2 - \mu^2}{\lambda^2 - \mu^2}} \tag{131}$$

and

$$- \frac{d V}{d n_2} = \frac{A C}{\mu \sqrt{\lambda^2 - \mu^2}} \tag{132}$$

The value of the potential gradient at any point in space.

The value of the constant A is that given in equation (**117**) and in order to determine the values of μ and λ in rectangular co-ordinates we have the relations given by equations (**109**) and (**111**). It will here be observed that the potential gradient is independent γ which is obvious from the symmetrical arrangement, that is, the potential gradient will be similar for any of the diametral planes γ = constant. Thus, we may write

$$\left.\begin{aligned} x &= c \sec \alpha \operatorname{sech} \beta \\ y &= c \tan \alpha \tanh \beta \end{aligned}\right\} \tag{133}$$

also,

$$\left.\begin{aligned} \lambda &= c \sec \alpha \\ \mu &= c \operatorname{sech} \beta \end{aligned}\right\} \tag{134}$$

These equations in combination with (**132**) enable us to calculate the potential gradient at any point in space in rectangular co-ordinates. (See Fig. 9.)

Digitized by Google

Curves of Constant Potential Gradient

The curves of constant potential gradient may now be obtained by putting

$$-\frac{dV}{dn_2} = G = \frac{Ac}{\mu\sqrt{\lambda^2 - \mu^2}} \tag{135}$$

Then

$$\mu\sqrt{\lambda^2 - \mu^2} = \frac{Ac}{G} \tag{136}$$

Thus for any given condition the right hand side of equation (**136**) is a constant. If we now substitute the values of λ and μ as given in equation (**134**) we may write

$$\sec\alpha = \pm\sqrt{\operatorname{sech}^2\beta + \frac{\left(\frac{A}{cG}\right)^2}{\operatorname{sech}^2\beta}}$$

or for purposes of calculation we may put for

$$\operatorname{sech}^2\beta = 1 - \tanh^2\beta$$

and we have

$$\sec\alpha = \pm\sqrt{(1 - \tanh^2\beta) + \frac{\left(\frac{A}{cG}\right)^2}{(1 - \tanh^2\beta)}} \tag{137}$$

where the values in terms of x and y are

$$\left.\begin{aligned} x &= c\sec\alpha\operatorname{sech}\beta \\ y &= c\tan\alpha\tanh\beta \end{aligned}\right\}$$

The curves of constant potential gradient as calculated from these equations are shown in Fig. 13.

Potential Gradient Along the X Axis

The value of the potential gradient at any point along the x axis between the origin and the focus may be obtained from equation (**132**) as follows:

From equation (**111**) we have

$$z = c\tan\alpha\tanh\beta$$

Digitized by Google

Now when $z = 0$

$$c \tan \alpha \tanh \beta = 0$$

and since $c \tanh \beta$ is not zero we have

$$\tan \alpha = 0$$
$$\alpha = 0$$

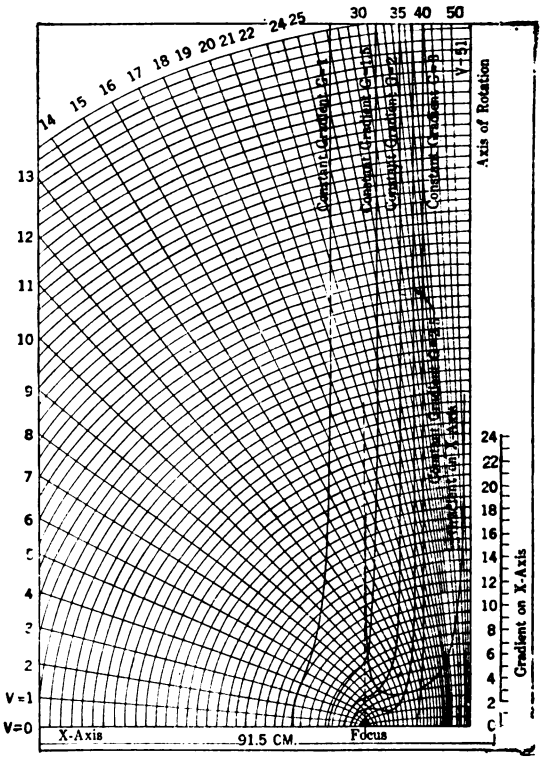


FIG. 13

Substituting this value of α in equation (**134**)

$$\lambda = c$$

and further upon substituting this value of λ in equation (**132**) we have

$$-\frac{d\,V}{d\,n_2} = \frac{A\,c}{\mu\sqrt{c^2 - \mu^2}} \qquad (138)$$

The potential gradient along the x axis.

Digitized by Google

Another method of obtaining the same result is to observe that the potential gradient along the x axis is merely $-\frac{dV}{d\mu}$ since the hyperbolas cut the x axis normally. Thus as we have seen

$$V = A\,\beta + C$$

Differentiating with respect to μ

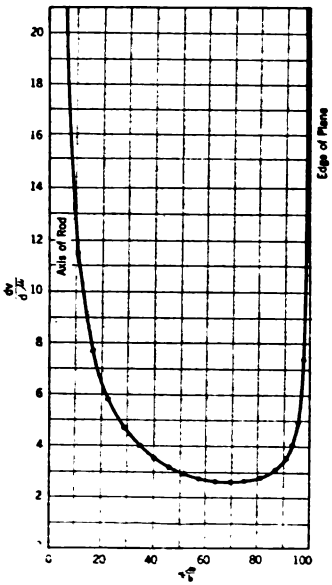


FIG. 14—CALCULATED POTENTIAL GRADIENT BETWEEN ROD AND EDGE OF PLANE

$$\frac{dV}{d\mu} = A\frac{d\beta}{d\mu}$$

Also,

$$\beta = \operatorname{sech}^{-1}\frac{\mu}{c}$$

Hence differentiating

$$\frac{dV}{d\mu} = A\frac{d\beta}{d\mu} = \frac{-Ac}{\mu\sqrt{c^2-\mu^2}}$$

Thus,

$$-\frac{dV}{d\mu} = \frac{Ac}{\mu\sqrt{c^2-\mu^2}} \qquad (139)$$

which is identical with equation (**138**) and is the potential gradient along the x axis between the origin and the focus. The potential gradient curve for this case is calculated and plotted in the curve Fig. 14.

Testing this equation for the values $\mu = 0$ and $\mu = c$ it will be observed that the potential gradient is infinite at the edge of the hole in the plane or focus and at the origin or along the z axis. A minimum value of the gradient will exist somewhere between these two limits. Its value will be found in the usual manner as

$$\frac{d}{d\mu}\left(\frac{dV}{d\mu}\right) = 0$$

Thus differentiating equation (**139**) with respect to μ and equating the result to zero we have

Digitized by Google

$$\frac{d^2 V}{d \mu^2} = \frac{A c [(c^2 - \mu^2) - \mu^2]}{\mu^2 (b^2 - \mu^2)^{3/2}}$$

$$= \frac{A c [(c^2 - 2\mu^2)]}{\mu^2 (b^2 - \mu^2)^{3/2}}$$

Equating to zero and observing that $A c$ is not zero we have

$$c^2 = 2 \mu^2$$

$$\mu = \frac{c}{\sqrt{Z}} \tag{140}$$

Thus the minimum value of the potential gradient occurs at this point which is about 71 per cent of the distance from the axis towards the edge of the hole in the infinite plane.

The potential gradient curve enables us to determine the proper size of central electrode so as not to over stress the dielectric. Or by selecting the hyperboloid which we choose to represent our tank with hole we can select a central electrode which has the same value of the potential gradient or any other value which we may desire for other reasons. Knowing the characteristics of our dielectric used we can determine the puncture voltage of the apparatus, etc.

Solution for the Tubes of Flow or Flux

The flux or flow across any area may be defined as the surface integral of the normal component of the flux density, and as we have seen from equations (**56**) and (**57**) this in turn is equal to the normal component of the potential gradient.

Thus,

$$\left.\begin{aligned} &\int\int -\frac{d V}{d n_2} d n_1 d n_3 \\ \text{or} \quad &\int\int_s -\frac{d V}{d n_2} d s_2 \end{aligned}\right\} \tag{141}$$

We have from equation (**132**)

$$-\frac{d V}{d n_2} = \frac{A c}{\mu \sqrt{\lambda^2 - \mu^2}}$$

Digitized by Google

We also have for the values of $d\,n_1$ and $d\,n_3$ or $d\,S_2$, equation (51)

$$d\,S_2 = d\,n_1\,d\,n_3 = \frac{d\,\lambda\,d\,\nu}{h_1\,h_3} \tag{142}$$

and from equations (65) and (69) we have

$$\frac{1}{h_1} = \sqrt{\frac{\lambda^2 - \mu^2}{\lambda^2 - c^2}}$$

$$\frac{1}{h_3} = \frac{\lambda\,\mu}{c\,(1 + \nu^2)}$$

Substituting these values in (142) we get

$$d\,S_2 = \sqrt{\frac{\lambda^2 - \mu^2}{\lambda^2 - c^2}}\left(\frac{\lambda\,\mu}{c\,(1 + \nu^2)}\right) d\,\lambda\,d\,\nu$$

and combining in equation (141) and simplifying we get

$$\int_{S_2}\int -\frac{d\,V}{d\,n_2}\,d\,S_2 = \frac{A\,\lambda}{\sqrt{\lambda^2 - c^2}\,(1 + \nu^2)}\,d\,\lambda\,d\,\nu$$

$$= A\int \frac{d\,\nu}{(1 + \nu^2)} \int \frac{\lambda\,d\,\lambda}{\sqrt{\lambda^2 - c^2}}$$

Integrating the first part between the limits $\nu = 0$ and $\nu = \nu_0$ we have,

$$\left[\tan^{-1}\nu + K\right]_{\nu=0}^{\nu=\nu_0} = -\tan^{-1}\nu_0$$

and since ν_0 may have any value we can neglect it as far as the spacing of the surfaces of flow are concerned. Integrating the second part between the limits $\lambda = \lambda_0$ and $\lambda = \lambda_1$ we have

$$\int_{\lambda=\lambda_0}^{\lambda=\lambda_1} \frac{\lambda\,d\,\lambda}{\sqrt{\lambda^2 - c^2}} = \left[\sqrt{\lambda^2 - c^2} + K\right]_{\lambda=\lambda_0}^{\lambda=\lambda_1}$$

Digitized by Google

That is we have

$$\int_{S_2} \int -\frac{d\,V}{d\,n_2}\, d\,S_2 = A\,(\sqrt{\lambda_0^2 - c^2} - \sqrt{\lambda_1 - c^2}) \tag{143}$$

If we now remember that from equation (**109**)

$$\lambda = c \sec \alpha$$

we may write

$$\int_{S_2} \int -\frac{d\,V}{d\,n_2}\, d\,S_2 = A\,C\,(\sqrt{\sec^2 \alpha_0 - 1} - \sqrt{\sec^2 \alpha_1 - 1}) \tag{144}$$

Also, $$\sec^2 \alpha - 1 = \tan^2 \alpha$$

Substituting we get

$$\int_{S_2} \int -\frac{d\,V}{d\,n_2}\, d\,S_2 = A\,(c \tan \alpha_0 - c \tan \alpha_1) \tag{145}$$

But it will be observed from Fig. 9 that $c \tan \alpha$ is the minor axis of an oblate spheroid, and, therefore, for equal tubes of flow the surfaces will have any constant spacing on the minor axis of the spheroid. (See Figs. 12 and 13.)

In the above work we have obtained the solution of the electrostatic problem in which any two confocal hyperboloids of revolution of one sheet and of the same family are maintained at definite potentials. The solution of this problem should be of interest to engineers as it furnishes us with a solution which may be applied as an approximation to many engineering problems. For example, it is a useful guide in studying the high-voltage bushing problem; it also gives us an interesting variety of possible electrode shapes for use in testing insulating materials, where it is very desirable to be able to calculate the gradients, etc., etc.

Another problem which should also be of considerable interest to engineers is the case when any two confocal hyperboloids of revolution of two sheets and of the same family are maintained at definite potentials. The solution of this problem may be applied as an approximation to another group of prob-

Digitized by Google

lems which are of frequent occurrence in engineering. For example, it may be applied to switch electrodes at various spacings; also as an approximation in vacuum-tube designs, such as X-ray tubes, kenotrons, etc. That is, it is an approximation to the group of problems of two elongated electrodes at various spacings, or such as an electrode and a plane (*i.e.*, two needle points or a needle and a plane).

The solution for this case is obtained in exactly the same manner as that described above except that in this case we select as our standard ellipsoid the prolate spheroid and express Laplace's equation in normal prolate spheroidal co-ordinates.

Two other problems namely, the distribution of the electrostatic field about the charged oblate or prolate spheroids are obtained in exactly the same manner.

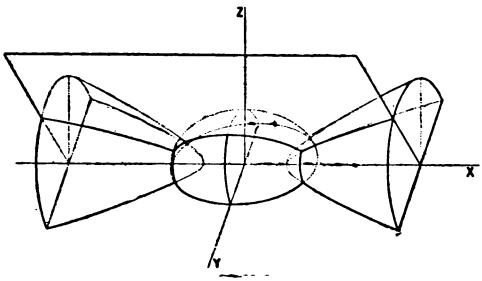


FIG. 15—INTERSECTION OF PROLATE SPHEROID, CONFOCAL HYPERBOLOID OF TWO SHEETS AND A PLANE THROUGH THE AXIS OF ROTATION

NORMAL PROLATE SPHEROIDAL CO-ORDINATES[39]

In this case we take for our standard ellipsoid the prolate spheroid, the axis of rotation is then the major axis and our plane must contain that axis. Taking the x axis as axis of rotation and the XY plane as plane of reference we have for the equation of our three orthogonal surfaces the following. (See Fig. 15).

$$\left.\begin{aligned} &\frac{x^2}{\lambda^2} + \frac{y^2}{\lambda^2 - b^2} + \frac{z^2}{\lambda^2 - b^2} = 0 \\ &\frac{x^2}{\mu^2} + \frac{y^2}{\mu^2 - b^2} + \frac{z^2}{\mu^2 - b^2} = 0 \\ &z - \nu y = 0 \end{aligned}\right\} \qquad (146)$$

39. See Byerly Fourier's Series and Spherical Harmonics, page 243, from which this discussion has been taken.

Digitized by Google

where $\lambda^2 > b^2 > \mu^2$

Here, b, is the semi-major axis of the prolate spheroid.

Solving the three equations simultaneously for the values of x, y, z as functions of λ, μ and ν as we did in the oblate spheroidal problem, and then differentiating these partially with respect to λ, μ and ν we will have functional equations as before, namely;

$$\frac{\partial x}{\partial \lambda} = f_1(\lambda, \mu, \nu)$$

$$\frac{\partial y}{\partial \lambda} = f_2(\lambda, \mu, \nu)$$

$$\frac{\partial z}{\partial \lambda} = f_3(\lambda, \mu, \nu)$$

and similar relations for x, y, z with respect to μ and ν. We also have as before

$$\left.\begin{aligned} \frac{1}{h_1^2} &= \left(\frac{\partial x}{\partial \lambda}\right)^2 + \left(\frac{\partial y}{\partial \lambda}\right)^2 + \left(\frac{\partial z}{\partial \lambda}\right)^2 \\ \frac{1}{h_2^2} &= \left(\frac{\partial x}{\partial \mu}\right)^2 + \left(\frac{\partial y}{\partial \mu}\right)^2 + \left(\frac{\partial z}{\partial \mu}\right)^2 \\ \frac{1}{h_3^2} &= \left(\frac{\partial x}{\partial \nu}\right)^2 + \left(\frac{\partial y}{\partial \nu}\right)^2 + \left(\frac{\partial z}{\partial \nu}\right)^2 \end{aligned}\right\}$$

and obtain the following values

$$\left.\begin{aligned} h_1^2 &= \frac{\lambda^2 - b^2}{\lambda^2 - \mu^2} \\ h_2^2 &= \frac{b^2 - \mu^2}{\lambda^2 - \mu^2} \\ h_3^2 &= \frac{b^2(1+\nu)^2}{(\lambda^2 - b^2)(b^2 - \mu^2)} \end{aligned}\right\} \quad (147)$$

Digitized by Google

From this we have

$$\left.\begin{aligned} d n_1 &= \frac{d\lambda}{h_1} = \sqrt{\frac{\lambda^2 - \mu^2}{\lambda^2 - b^2}}\, d\lambda \\ d n_2 &= \frac{d\mu}{h_2} = \sqrt{\frac{\lambda^2 - \mu^2}{b^2 - \mu^2}}\, d\mu \\ d n_3 &= \frac{d\nu}{h_3} = \sqrt{\frac{(\lambda^2 - b^2)(b^2 - \mu^2)}{b^2(1+\nu^2)^2}}\, d\nu \end{aligned}\right\} \quad (148)$$

and Laplace's equation in terms of our spheroidal co-ordinates λ, μ and ν becomes.

$$\frac{1}{b^2(1+\nu^2)}\frac{\partial}{\partial\lambda}\left[(\lambda^2 - b^2)\frac{\partial V}{\partial\lambda}\right] + \frac{1}{b^2(1+\nu^2)} = \frac{\partial}{\partial\mu}\left[(b^2 - \mu^2)\frac{\partial V}{\partial\mu}\right] + \frac{\lambda^2 - \mu^2}{(\lambda^2 - b^2)(b^2 - \mu^2)}\frac{\partial}{\partial\nu}\left[(1+\nu^2)\frac{\partial V}{\partial\nu}\right] = 0 \quad (149)$$

and reduces in exactly the same manner as the oblate spheroid problem to

$$\frac{1}{\lambda^2 - b^2}\frac{\partial^2 V}{\partial\alpha^2} + \frac{1}{b^2 - \mu^2}\frac{\partial^2 V}{\partial\beta^2} + \frac{\lambda^2 - \mu^2}{(\lambda^2 - b^2)(b^2 - \mu^2)}\frac{\partial^2 V}{\partial\gamma^2} = 0 \quad (150)$$

Where

$$\left.\begin{aligned} d\alpha &= -\frac{b}{\lambda^2 - b^2}\, d\lambda \\ d\beta &= \frac{b}{b^2 - \mu^2}\, d\mu \\ d\gamma &= \frac{1}{1+\nu^2}\, d\nu \end{aligned}\right\} \quad (151)$$

Digitized by Google

$$\left.\begin{aligned} \alpha &= \coth^{-1}\frac{\lambda}{b} \\ \beta &= \tanh^{-1}\frac{\mu}{b} \\ \gamma &= \tan^{-1}\nu \end{aligned}\right\} \tag{152}$$

or,

$$\left.\begin{aligned} \lambda &= b\coth\alpha \\ \mu &= b\tanh\beta \\ \nu &= \tan\gamma \end{aligned}\right\} \tag{153}$$

Substituting these values in equation (**150**) we obtain Laplace's equation in the form

$$\sinh^2\alpha\frac{\partial^2 V}{\partial\alpha^2}+\cosh^2\beta\frac{\partial^2 V}{\partial\beta^2}+(\sinh^2\alpha+\cosh^2\beta)\frac{\partial^2 V}{\partial\gamma^2}=0 \tag{154}$$

In using this equation it is to be noted that the point (α, β, γ) is the point of intersection of a prolate spheroid whose semi-axes are

$$\left.\begin{aligned} &b\coth\alpha \text{ major} \\ &b\operatorname{coch}\alpha \text{ minor} \end{aligned}\right\} \tag{155}$$

a biparted hyperboloid of revolution whose semi-axes are

$$\left.\begin{aligned} &b\tanh\beta \text{ transverse axis} \\ &b\operatorname{sech}\beta \text{ conjugate axis} \end{aligned}\right\}$$

and a plane containing the axis of revolution and making the angle γ with a fixed plane. If the fixed plane of reference is that of XY the rectangular co-ordinates of any point in space (α, β, γ) are

$$\left.\begin{aligned} x &= b\coth\alpha\tanh\beta \\ y &= b\operatorname{csch}\alpha\operatorname{sech}\beta\cos\gamma \\ z &= b\operatorname{csch}\alpha\operatorname{sech}\beta\sin\gamma \end{aligned}\right\} \tag{156}$$

Digitized by Google

and α may range from $+\infty$ to 0, β from $-\infty$ to $+\infty$, and γ from 0 to 2π. Negative values of β are to be taken for points lying to the left of a plane through the origin perpendicular to the axis of revolution; in this case, to the left of the YZ plane. (See Fig. 16).

Potential at any Point in Space

If we are given the potentials of any two confocal hyperboloids of two sheets, that is, for any two values of β we can obtain the potential at any point in space between them. For in that case we have seen exactly as in the oblate spheroid problem that V is a function of β only, hence in Laplace's equation

$$\frac{\partial^2 V}{\partial \alpha^2} = 0 \text{ and } \frac{\partial^2 V}{\partial \gamma^2} = 0$$

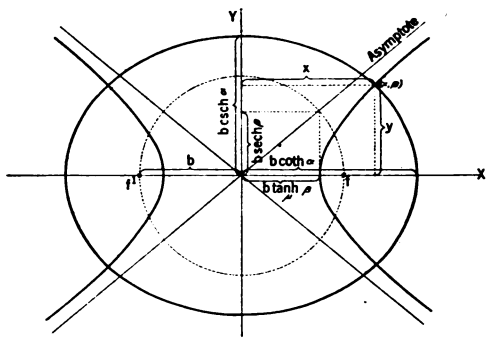


Fig. 16—Confocal Elipse and Hyperbola

Since $\cosh^2 \beta$ is not equal to zero for all values of β Laplace's equation reduces in our case to

$$\frac{\partial^2 V}{\partial \beta^2} = 0 \tag{157}$$

The solution of which is seen to be

$$V = A\,\beta + C \tag{158}$$

The constants A and C will be determined from the boundary conditions of the problem as before.
Assuming the case

$$\left.\begin{aligned} V &= 0 \text{ when } \beta = 0 \\ V &= V_1 \text{ when } \beta = \beta_1 \end{aligned}\right\} \tag{159}$$

Digitized by Google

Substituting these values in equation (158) we get

$$\left.\begin{aligned} C &= 0 \\ A &= \frac{V_1}{\beta_1} \end{aligned}\right\}$$

Thus we may write our solution under these boundary conditions simply as

$$V = A\ \beta \tag{160}$$

or since $\beta = \tanh^{-1} \frac{\mu}{b}$

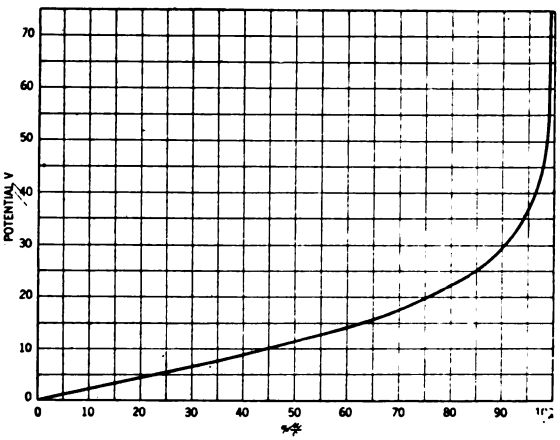


FIG. 17—CALCULATION OF POTENTIAL DISTRIBUTION ALONG THE X-AXIS

we may write it in terms of μ and b as follows.

$$V = \frac{V_1}{\tanh^{-1} \frac{\mu_1}{b}} \tanh^{-1} \frac{\mu}{b} \tag{161}$$

This equation enables us to calculate the potential at any point along the x axis between the foci and has been plotted in Fig. 17 attached.

A diagram of the field has been constructed in the same manner as described above for the oblate problem. (See Fig. 18).

Digitized by Google

Potential Gradient at any Point in Space

The potential gradient will be

$$\frac{d\,V}{d\,n_2} = A\,\frac{d\,\beta}{d\,n_2} \tag{162}$$

where $d\,n_2$ is the elementary normal to the surface of the hyperboloid (say for $\mu = \mu_0$) under consideration. The sign $\frac{d\,V}{d\,n_2}$

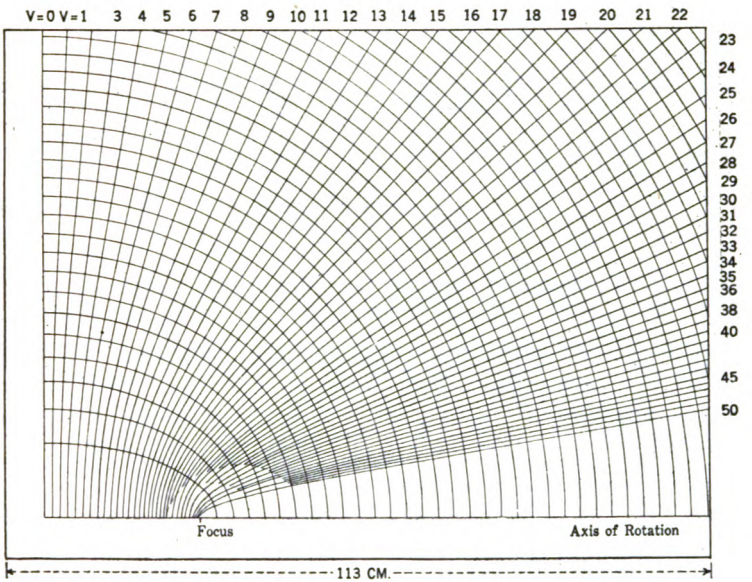


FIG. 18

which expresses the potential gradient is here taken as positive that is, $d\,n_2$ is assumed to be in the direction of increasing potential.

In order to determine β we have the relation

$$\beta = \tanh^{-1}\frac{\mu}{b}$$

Hence,

$$\frac{d\,\beta}{d\,\mu} = \frac{b}{b^2 - \mu^2} \tag{163}$$

Digitized by Google

We also have

$$d n_2 = \frac{d \mu}{h_2}$$

$$d n_2 = \sqrt{\frac{\lambda^2 - \mu^2}{b^2 - \mu^2}}\, d \mu$$

and

$$\frac{d \mu}{d n_2} = \sqrt{\frac{b^2 - \mu^2}{\lambda^2 - \mu^2}} \tag{164}$$

Thus for the gradient we have from equations (**163**) and (**164**)

$$\frac{d V}{d n_2} = A \frac{d \beta}{d \mu} \frac{d \mu}{d n_2} = A \frac{b}{b^2 - \mu^2} \sqrt{\frac{b^2 - \mu^2}{\lambda^2 - \mu^2}}$$

Simplifying

$$\frac{d V}{d n_2} = \frac{A b}{\sqrt{(b^2 - \mu^2)(\lambda^2 - \mu^2)}} \tag{165}$$

which is the potential gradient at any point in space. It is observed that the potential gradient is independent of γ as is obvious from the symmetry of the problem. We may, therefore, express the potential gradient at any point in space in rectangular co-ordinates with the help of the following relations (See Fig. 16).

$$\left.\begin{aligned} \lambda &= b \coth \alpha \\ \mu &= b \tanh \beta \end{aligned}\right\}$$

and

$$\left.\begin{aligned} x &= b \coth \alpha \tanh \beta \\ y &= b \operatorname{csch} \alpha \operatorname{sech} \beta \end{aligned}\right\}$$

Curves of Constant Potential Gradient

The curves of constant potential gradient may now be obtained by putting equation equal to the various constant values desired.

Thus,

$$\frac{d V}{d n_2} = G = \frac{A b}{\sqrt{(b^2 - \mu^2)(\lambda^2 - \mu^2)}}$$

$$\sqrt{(b^2 - \mu^2)(\lambda^2 - \mu^2)} = \frac{A b}{G} \tag{166}$$

Digitized by Google

Thus for any given condition and value of potential gradient G the right hand member of this equation is a constant.

If we now substitute the values of λ and μ we may write it for the purpose of calculation.

$$\coth \alpha = \pm \sqrt{\tanh^2 \beta + \frac{\left(\frac{A}{G\,b}\right)^2}{\operatorname{sech}^2 \beta}}$$

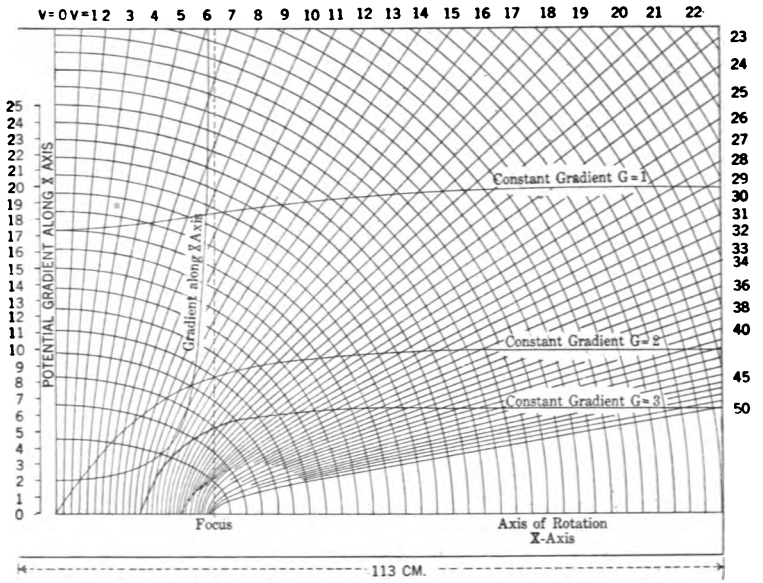

V=0 V=1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
23 24 25 26 27 28 29 30 31 32 33 34 36 38 40 45 50
25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
POTENTIAL GRADIENT ALONG X AXIS
Gradient along Y Axis
Constant Gradient G=1
Constant Gradient G=2
Constant Gradient G=3
Focus
Axis of Rotation
X-Axis
113 CM.

FIG. 19

or if tables of $\operatorname{sech}^2 \beta$ are not available we can write it

$$\coth \alpha = \pm \sqrt{\tanh^2 \beta + \frac{\left(\frac{A}{G\,b}\right)^2}{1-\tanh^2 \beta}} \qquad (167)$$

The values of x and y are

$$\left.\begin{aligned} x &= b \coth \alpha \tanh \beta \\ y &= b \operatorname{csch} \alpha \operatorname{sech} \beta \end{aligned}\right\}$$

The curves of constant potential gradient as calculated from these equations are shown in Fig. 19.

Digitized by Google

Potential Gradient Along the X Axis

The value of the potential gradient at any point along the x axis between the origin and the foci may be found directly from the general equation (**165**) or independently as $\frac{dV}{d\mu}$.

It is the value obtained when $y = 0$

$$y = 0 = b \operatorname{coch} \alpha \operatorname{sech} \alpha$$

and since $b \operatorname{sech} \beta$ is not zero we have

$$\operatorname{csch} \alpha = 0$$

$$\frac{1}{\sinh \alpha} = 0$$

$$\alpha = \infty$$

Substituting this value in the equation

$$\lambda = b \coth \alpha$$

we have $\coth \infty = 1$

and $\lambda = b$

Hence substituting $\lambda = b$ in our equation (**165**) for the potential gradient we get

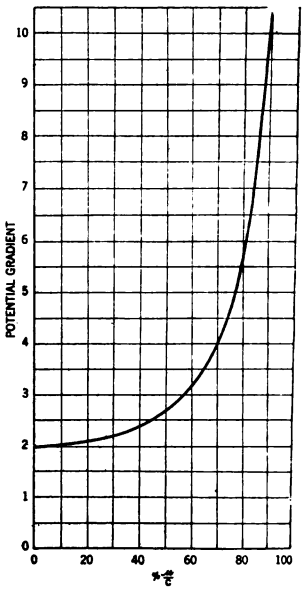


Fig. 20—Calculated Potential Gradient along the X-Axis

$$\frac{dV}{dn_2} = \frac{Ab}{\sqrt{(b^2 - \mu^2)(b^2 - \mu^2)}} = \frac{Ab}{b^2 - \mu^2} \qquad (168)$$

for the value of the potential gradient along the x axis between the foci. The curve is shown in Fig. 20.

Solution for the Tubes of Flow of Flux

The total flux across any area may be defined as the surface integral of the normal component of the flux density; in the case of air dielectric, flux density and gradient are equivalent. We may, therefore, write it

$$\int\int \frac{dV}{dn_2} dn_1 dn_3 = \int_{S_2} \int \frac{dV}{dn_2} dS_2$$

Digitized by Google

we have seen that

$$\frac{d\,V}{d\,n_2} = \frac{A\,b}{\sqrt{(b^2-\mu^2)\,(\lambda^2-\mu^2)}}$$

$$d\,n_1 = \sqrt{\frac{\lambda^2-\mu^2}{\lambda^2-b^2}}\,d\,\lambda$$

$$d\,n_3 = \sqrt{\frac{(\lambda^2-b^2)\,(b^2-\mu^2)}{b^2\,(1+\nu^2)^2}}\,d\,\nu$$

Substituting these values and simplifying we get

$$\int\int \frac{A}{1+\nu^2}\,d\,\lambda\,d\,\nu$$

As far as the spacing of the surfaces of flow is concerned we may neglect the integration with respect to ν by reason of the symmetry of the tubes of flow about the axis of rotation.
We thus have,

$$\int_{S_2}\int \frac{d\,V}{d\,n_2}\,d\,S_2 = A\,(\lambda_0-\lambda_1)$$

But we have seen that

$$\lambda = b\coth\alpha$$

also that $b\coth\alpha$ is the major semi-axis of the prolate spheroids. Therefore, equal tubes of flux will be obtained by taking equal spaces along the major axis of the spheroids. (See Figs. 18 and 19).

Digitized by Google

Digitized by Google

Presented at the 333d Meeting of the American Institute of Electrical Engineers, Philadelphia, Pa., October 8, 1917.

Copyright 1917. By A. I. E. E.
(*Subject to final revision for the Transactions.*)

INDUSTRIAL RESEARCH WITH SOME NOTES CONCERNING ITS SCOPE IN THE BELL TELEPHONE SYSTEM

BY F. B. JEWETT

ABSTRACT OF PAPER

The interrelation of industrial and "pure science" research and the restrictions which must be imposed to insure mutual existence. A brief outline of the scope and progress of industrial research in the Bell Telephone System.

IT IS with a feeling half of diffidence and half of apology that I venture to present a paper on industrial research at this time to the members of this great engineering organization. The diffidence arises from the fact that for the past few years, and particularly since the outbreak of the great world war, the terms, the emblems and the forms of industrial research, if not always the realities, have been so much a part of the industrial daily life of the nation that the working of them together in a paper seems trite and somewhat of a reflection on the intelligence of the Institute membership. The feeling is akin to that which many of us have experienced when, after numerous courses in mathematics which have made its general processes seem rather second-nature to us, we begin the study of logic and find there a detailed explanatory discussion of these processes. The query at once arises as to why anyone should care to write about matters so obvious, let alone why anyone should waste his time in the reading and studying of such writings. Under these conditions it is clear that to be of interest and value any paper on industrial research should be most carefully thought out and worked over. My apology to the members of the Institute results from the conditions under which I have labored for the past four or five months. The calls upon my time and energies for war work have been so great as to make the careful preparation just referred to impossible. In other words, the doing of industrial research has, for the time being, shouldered out the

Manuscript of this paper was received October 22, 1917.

Digitized by Google

thinking and writing about industrial research. What follows must therefore be read with the understanding that it is the hurried jotting down of ideas which have been scattered and relegated to the background by the ceaseless day by day pressure for the results of industrial research in the grim game of human destruction.

Much has been said and columns have been written on the wonderful achievements of industrial research in the past and on the stupendous effects which are to follow from industrial researches not yet undertaken. In fact, it seems to be the exception rather than the rule for a present day conversation to run its course without some reference to industrial research or its results. Under the circumstances it is sometimes surprising to find how little actual knowledge seems to exist as to what really constitutes industrial research or of the relations which it bears to research which is not industrial. On the other hand, we are frequently surprised by the evidences of real industrial research in hitherto unsuspected places. That industrial research has taken a firm place in shaping the destinies of our economic future, no one who is at all cognizant of the facts would for a moment deny. A partial picture of present conditions in the United States is interestingly shown in a recent paper entitled "Industrial Research in the United States of America" by Mr. A. P. M. Fleming, M. I. E. E.

As might be expected in a departure so radical and relatively so new, the processes of industrial research have not as yet been applied to the various arts in anything like a uniform manner. A survey of present day conditions in the United States discloses the greatest progress in and the greatest results from industrial research in large electrical, chemical and metallurgical industries, where real scientific research methods were first applied and where its application has been carried to the greatest extreme. The electrical industries have been particularly fortunate in this respect, due largely to the fact that they had no generation-long traditions to overcome and to the further and more important fact that a large proportion of the leaders have been men educated in technical schools and universities where the spirit of scientific research prevails. Under these conditions it is not strange that the value of industrial research should early have been recognized as a vital necessity in the electrical industries, nor that the methods of scientific research should have become so closely interwoven in all its processes. So effectually has this

Digitized by Google

dependence on research methods been established in the larger electrical manufacturing organizations that no question is ever raised as to the proper method of attacking a problem or a difficulty. Not only do we look to the established research departments for the production of most of that which is radically new in the art but they have become and are, either directly or indirectly, our haven of succor when some particularly difficult and knotty problem arises. It is difficult for those of us who have lived and worked long in this environment to appreciate any attitude of mind but the one which seeks the answer to a radically new problem in the processes of scientific research. Thus far have we progressed from the era of the cut and try method—an era productive of much that was of inestimable value to the world. In comparing the present and prospective future with the past, we should also not lose sight of the fact that our so-called scientific methods would be of little avail were it not for the accumulation of facts laboriously dug out by empirical methods at a time when such methods were the only ones that could be applied.

While the development and beneficial results of industrial research are most apparent in the larger industries, where they were first applied and where funds have been available for a continuation of the work during the period when scientific methods were on trial, the signs are numerous which indicate the rapid extension of scientific research to the smaller industries. These signs are shown principally in the growth of industrial research laboratories established for the purpose of assisting clients with research facilities in much the same way that consulting engineers have long assisted in engineering matters; also in the formation of centralized research establishments destined to serve an association of individual manufacturers engaged in the same or similar lines of work. That this growth of industrial research will continue at an ever-increasing rate seems beyond question. The results thus far obtained leave no doubt as to the value of scientific methods when applied to industry and the truth of these results is becoming each day more clearly evident to the rank and file of those engaged in the production of material things. The process of this evolution of thought and application is well illustrated by Macauley in his "Science of Government," where he says "First come hints, then fragments of systems, then defective systems. The sound opinion, held for a time by one bold speculator,

Digitized by Google

becomes the opinion of a small minority, of a strong majority, of the majority of mankind. Thus the great progress goes on.'

That the great war on which we are embarked is exerting an enormous, stimulating influence on the extension of industrial research is clearly evident. The limits, both in time and extent, seem now to be determined merely by the ability to obtain specially trained men and women and the ability of the present industries and their workers to absorb properly the serum of the new inoculation. While very great benefits will undoubtedly accrue from this extension of scientific research methods into the arts and industries where it has not hitherto penetrated, very grave dangers undoubtedly attend the present forced growth. These dangers are two-fold in character. In the first place, with the enormous demand for research workers and with the glowing prospects of hitherto undreamed of accomplishments, many men will undoubtedly undertake so-called research work for which they are essentially unfitted, both as to mentality and training. At the same time, alleged research activities will be started on a large scale in places where there is little or no present call for such activities or where the nature of the problems is such as to necessitate a gradual building up of the research function. These two correlated factors, which are not at all unique to industrial research, since they in one way or another attend the publication of every new and useful achievement, will undoubtedly result in temporary reactions against the scientific method and in favor of the so-called "practical method" The extent to which these reactions will prove deleterious to the general early extension of scientific methods of the various industries will depend very largely on the control and guidance which is exercised in the next few years and on the ability of our universities and technical schools to meet the large demands for capable, scientifically trained men which will be thrust upon them.

This brings us to the second of the dangers, namely, the possibility that the pressure of industrial research may react on universities and technical schools in such a way as to cripple them in their essential functions as a part of the general scheme of national economic development. In the chaos attendant upon the growth and development of this new element of our industrial fabric there has been a great deal of uncertainty as to the relations between so-called "pure" and industrial researches and the relation of the university to the industrial

Digitized by Google

research laboratory and its problems. A part of this chaotic condition is inherent in the nature of a situation which requires much experimentation before the road to the answer is clearly marked out. A part, however, is undoubtedly due to failure properly to analyze the situation and assign to each element in the research program its real sphere of utility.

The relations between pure and industrial research and between the university laboratory and the industrial laboratory were very fully considered and very clearly set forth by Colonel J. J. Carty in his Presidential Address at the annual meeting of this Institute in Cleveland in 1916. Colonel Carty pointed out that much of the confusion now existing was due to the fact that the *methods* employed in pure or academic research and industrial research were identical and that from this had arisen a confusion of ideas based on the assumption that identity or lack of identity in the method was the yard-stick by which research was to be designated as pure or industrial. Colonel Carty pointed out that the real distinction lay in the motive behind the research and not at all in the methods employed. In other words, two investigators starting from essentially the same basis of fact and pursuing practically identical paths to practically identical conclusions could be, the one a performer of industrial research with a purely utilitarian motive, and the other a delver in pure research for the purpose of enlarging the bounds of human knowledge and with no immediate utilitarian aim in view.

If, as Colonel Carty points out, the question of motive is the essential determining factor which differentiates pure and industrial research, a thorough appreciation of this fact should tend to clarify the situation as concerns the functions of academic institutions and their research laboratories in the industrial research problem.

Viewed from the standpoint of motive, there would appear to be but little place in an academic institution or its laboratories for real industrial research. Per contra, there would appear to be but little place for so-called "pure" research in a strictly industrial organization. It does not necessarily follow from this that an academic institution should engage in no industrial research, nor that an industrial institution should never undertake problems of pure research, for, on the one hand a certain direct and limited participation in industrial research may be the best way to advance pure scientific research and the development

Digitized by Google

of men, while on the other hand, limited excursions into the realms of pure science may react to the best interests of the industrial laboratory and its staff and be productive of real and worthwhile extensions of the realm of knowledge. In such cases, however there should be no misunderstanding as to the governing motives.

Viewed in the broadest possible way and considered as a part of a complete national organization, industrial and academic or pure science research laboratories are, of necessity, very closely associated and must grow together and with the same relative vigor if the best interests of civilization are to be served. It is difficult to see how either could completely supplant the functions of the other. On the one hand, the academic institution, with its pure research laboratories, is engaged primarily in the education and development of men trained in scientific methods and in extending the realms of knowledge for the benefit of mankind and without any particular utilitarian motive. On the other hand, the industrial research organization is engaged primarily in the utilization of trained scientists for the solution of utilitarian problems; in other words, in the cultivation of the regions discovered and mapped out by the experimenters in pure science. The industrial research organization is not a general educational institution and from its very nature cannot take over that function of the university and technical school which has to do with the fundamental training of men. Further, since it is part and parcel of an institution, whose primary object is avowedly commercial production for the sake of monetary gain, and all of whose funds are derived from the sale of its wares, it cannot usurp in any large measure the functions of the university or the pure science research foundation without raising a grave question of ethics involving the body politic.

If, therefore, the university and technical school are primarily what we have long considered them to be, namely, institutions for the training of men and for the carrying on of researches designed to enlarge the bounds of knowledge, and if, on the other hand, industrial research organizations are institutions which utilize the human product and the advances of the universities in utilitarian adaptations, it follows that there is and can be no serious competition between the two, for, on the one hand, if the university or technical school should attempt to enter too largely into the realm of industrial research it would run the very grave risk of destroying its primary functions by

Digitized by Google

the establishment of an atmosphere highly prejudicial to the broad training of men or to pure scientific research. On the other hand, the industrial research organization is not equipped to undertake the general work of the university either in the training of men or the conducting of pure research, nor can it afford to do so. From the very nature of its genesis, the utilitarian object is the motive controlling it. To be sure, occasional pieces of pure scientific research may from time to time emerge from the industrial laboratory, but this work will be small in comparison with the sum total of accomplishment in its proper field.

But to succeed in its proper field industrial research must receive a continual stream of capable men and women thoroughly trained in methods of scientific research, thoroughly grounded as to the geography of knowledge, and competent to appreciate any extensions in its boundaries and capable of immediately cultivating such extensions for the benefit of the particular industrial research organization with which they are connected. Any failure in the supply of men or any failure to advance the bounds of knowledge by pure scientific research will result inevitably in a strict limitation of industrial research. In referring to the work of the early chemists and alchemists, Sir William Tinney remarks that until men began to observe and interrogate nature for the sake of learning her ways and without concentrating their attention on the expectation of useful applications of such knowledge, little or no progress was made. In other words, until a sufficient foundation of pure science has been successfully laid there can be no applied science.

In considering the part which the educational institutions should play in the solution of research problems for industrial organizations, there are other factors which should not be lost sight of. As already indicated, there would appear to be a very real and imminent danger to its pure research function if the educational institution were to embark largely on the solution of industrial problems for commercial organizations. Such a course would establish an attempt to maintain in the same institution two sets of research activities impelled by antipodal motives. On the one hand would be the group of pure scientific investigators, whose impelling motive was the desire to explore unknown regions and extend the bounds of knowledge without any thought of the immediate practical application of

Digitized by Google

the results of their work. The measure of their achievements would be the number and extent of the new facts brought to light. On the other hand, the industrial research group would be involved solely in the practical results of their work and the measure of their success would be an amount of money made or saved.

This state of affairs, involving the existence in the same institution of two groups using the same methods but impelled by different motives, would not itself be serious if the financial situation of the individual workers was relatively the same. Unfortunately, this is never the case. Having a monetary motive, success in industrial research is measured largely by a monetary reward and there would be, therefore, a strong tendency for industrial research workers in the educational institution to command and obtain larger emoluments than their confreres in the pure research field. Since academic salaries are, in the main, notoriously low, any scheme which would raise the general income of the industrial research worker above that of his co-worker in the pure research field would produce dissatisfaction and discontent and what is worse, a tendency for the major part of research ability to gravitate into the industrial field. Occasional exceptional instances of men so imbued with the love of scientific research that the question of monetary return is wholly secondary cannot outweigh the fact that in the great majority of cases the needs of life and family for the material necessities and comforts of life are a far stronger force in determining a man's actions than any other.

There is another factor of quite a different character which must be reckoned with. This is the element of human nature in man as at present constituted and as exemplified in the legal rules which he has evolved for the proper guidance of his affairs. Roughly speaking, in the material aspects of life human beings expect to enjoy for a time at least, the exclusive results of their efforts. This is certainly true in the realm of industrial research where those who advance money for its promotion expect to enjoy the proceeds which flow from its results. This is neither an unnatural nor an unworthy aspiration, but it does raise a considerable question as to the policy of an educational and pure research institution entering upon a relation with the providers of funds which would tend to limit definitely the freedom of the institution in certain directions. For centuries early and full publication of the results of scientific research has been a

Digitized by Google

cherished prerogative of the research worker and of the institution with which he was connected. If the institution is now to enter into a commercial relation with individuals and groups whereby it is to undertake the solution of their problems with the help of funds which they provide, it must expect to become in essence, merely a part of their organization and be governed to a large extent by the rules which govern in the commercial field. Not the least of these rules is the one which ordains that the results of industrial research shall be the exclusive property of those who accomplish it, either by being maintained in secret or by being protected by patent.

The welfare of the university and the technical school in their proper functions should therefore be a matter of the gravest concern to all who are engaged or interested in industrial research and we should be continually on the alert to see that their facilities are ample and functioning to full efficiency. From the standpoint of the writer, these facilities should be mainly those which will enable them to attack broadly problems of fundamental scientific research—the facilities for industrial research being provided either by the individual industries themselves, by associations of manufacturers, or through the medium of industrial research laboratories equipped to undertake the solution of problems for clients. While these latter would, of course, be self-sustaining, they would not necessarily be money-making institutions in the ordinary sense.

The second of the dangers of the present situation referred to above is that under the enormous pressure for industrial research, engendered by war conditions, too large a proportion of the men capable of pure scientific research and the instruction of other men may be drawn away from their proper field of endeavor. If this withdrawal is but temporary and for the duration of the war, no great harm will probably result. If, on the other hand, there is danger that the withdrawals will be permanent, the results for the next decade will be serious indeed, since we will have erected the skeletons of huge industrial research organizations and find ourselves confronted with an inadequate supply of properly trained men to carry on the work. Further, there will be a long continued cessation of explorations in those regions where exploration is most needed. For the good of the nation no stone should therefore be left unturned to provide suitable research facilities in a suitable research environment for every man who shows that he has that element of originality, without which progress is impossible.

Digitized by Google

From what has been written in the foregoing paragraphs it occurs to me that I may possibly have trenched too largely on the scope of the papers to be covered by Mr. Skinner and Profesor Kennelly. If so, my excuse is that I have not had opportunity to consult with them and also that it is difficult for me to set forth my ideas on industrial research without, at the same time, stating my viewpoint on the relations of industrial to pure or institutional research. Further, as my point of view may not be identical with that of the other writers, some useful purpose may be served by its presentation.

Having set forth certain conditions which seem to me fundamental and certain situations which appear to confront all of us who are interested in the progress of industrial research, it may not be uninteresting to outline briefly the scope and progress of industrial research in the Bell Telephone System.

The aim of this research is frankly utilitarian in character. The main and never-lost-sight-of aim of the work is the advancement of intelligence communication telephonically and telegraphically by the application of the best scientific methods to the solution of the innumerable problems which arise. In the present stage of development the arteries of industrial research permeate a very large part of the organization. This considerable utilization of scientific research methods is not the result of a mushroom growth but is a gradual evolution through the experience of many years. All of this experience has tended to confirm our conclusions that real advances in the art of telephony and telegraphy are to be looked for only in the results of broad-minded and painstaking research work. For many years, therefore, the constant effort has been to provide an ample staff of capable men, specially trained in scientific methods, and to place at the disposal of this staff whatever was necessary in the way of material facilities or human assistance. In common with many other industries engaged in the development of industrial research, the principal difficulty that has been experienced has been the securing of a sufficient number of trained workers. While not necessarily a reflection on the colleges, universities and technical schools, since their problem was a huge one, it is undoubtedly true that they have not in the past been able to secure, train and supply a sufficient number of skilled men and women to meet the evergrowing demands of industrial research. The result is that we of the Bell Telephone System are today confronted with a very large number of problems of the utmost

Digitized by Google

importance in the advancement of national and international communication work, and it is only through the greatest exertions that we have been able to secure and organize the specially trained force needed for their solution.

A common and not unnatural mistake concerning industrial research is that its field is limited very largely to the solution of laboratory problems. I venture to say that if a hundred educated and intelligent people in the ordinary pursuits of life were asked their ideas as to what constituted industrial research the great majority of them would picture some sort of a building or buildings in which men were experimenting with bottles and glasses and chemicals or with mechanical or electrical instruments of some sort. Although the work which goes on in laboratories such as these is a vital and essential part of the industrial research problem, it is by no means the whole of its sum and substance. In order to make the work of the laboratory investigator of maximum efficiency it is necessary in some way or other to formulate the requirements of his problems so that he may direct his energies along the straightest path to the desired goal. In many cases it is further necessary in some way to investigate carefully the products of laboratory work from the standpoint of their adaptability to commercial requirements and to the re-actions which they may bring about in more or less unexpected places. All of this follows directly from the fact frequently lost sight of, that what should be done depends in large measure on what can be done, and what can be done in turn on what it is essential to do. In other words, it is the old problem of the gun, the projectile and the armor in a slightly modified form. While a little thought indicates the necessity for a proper correlation between a study of requirements, the formulation of the problems to be solved, the carrying on of the research, and a test of its results in their practical application, it is clear that no hard and fast scheme of organization, applicable alike to all industries, can be laid down. In fact, it seems that the proper methods are almost as numerous as the types of industry to be served and that they range from a condition, on the one hand, where the entire problem is undertaken by the man who actually performs the research to the other extreme, where each phase of the problem is in the hands of separate individuals, no one of whom encroaches in the slightest degree upon the field of his co-worker.

As exemplified in the Bell Telephone System, the carrying on of industrial research does not lie at either of the above extremes,

Digitized by Google

although possibly it may approach slightly nearer to the latter than to the former condition.

Broadly speaking, the organization of our industrial research can be divided into two main subdivisions:

1. That part which is performed in the central Engineering Department of the American Telephone and Telegraph Company; and
2. That part which is performed in the centralized laboratories of the Western Electric Company.

In the first of these two divisions originate many of the requirements which call for the application of industrial research. This group, which constitutes in a way the central research department of the Bell System, is under the immediate direction of the Chief Engineer of the American Telephone and Telegraph Company, who has likewise general direction of the research problems undertaken by the second of the groups. The equipment of this group consists not of laboratories and apparatus but of highly trained human beings, the whole forming an organization capable of passing expert judgment on any of the vast number of problems continually arising in the System. In this central analytical research department are conducted not only the studies tending to correlate the requirements for the specific research work needed by the Bell Companies, but also those broader studies of fundamental requirements of growth in an ever-expanding electrical intelligence communication system. The necessity for a group of this kind, equipped in the manner indicated, is the result of our years of experience with other and what now appear to be essentially faulty alternatives.

From this first division of the research organization originate in large measure the sailing directions which govern the course of the physical and chemical researches carried on in the centralized laboratories of the Western Electric Company. Without these sailing directions it would be impossible to carry on much of the work of the centralized laboratories, which is now productive of results of great value. Before passing to an outline of the work of this second division, there is one point which should be clearly understood. This is the fact that while the research work of the Bell System is divided into the two main and essentially non-overlapping divisions noted above, it is not to be understood that the work of each of these divisions is carried on wholly independently of that of the other. Each group is in constant and direct communication with the other group and there is

Digitized by Google

nothing of the idea of a separate cell organization in the arrangement. In other words, there is no thought that the work in the first division will be entirely completed without consultation with those in the second division, or that of the second division without consultations with those in the first division. For example, in the formulation by engineers of the first division of a problem to be investigated in the physical or chemical research laboratories, the research men of these laboratories are drawn into the work in a preliminary way to avoid, so far as possible, any chance of such formulation as would result negatively or involve a large expenditure of time and money in essentially useless work. Very frequently this preliminary participation of the laboratory research workers modifies the requirements which were originally thought proper.

As indicated above, the physical, chemical and mechanical research laboratories of the entire Bell System are centralized in the Western Electric Company and are under the immediate direction of its Chief Engineer. This centralization of laboratory facilities was adopted after a number of years' trial of other arrangements, involving at one time three large separate laboratories. The experience of the past ten years has indicated clearly the desirability of the present arrangement in the System as now constituted. First and foremost, it makes available an extent of plant and staff not otherwise economically possible. It also tends to a more efficient utilization of this plant and staff on the major problems of the System by eliminating practically all duplication of effort, which previous experience indicated to be inevitable in a non-centralized laboratory organization. Finally, and not by any means least in importance, is the material advantage of having the research laboratories closely associated with the manufacturing part of the System. This advantage is the direct consequence of the fact that practically all of the results of our research work find their immediate fruition in physical apparatus which is to be constructed in large quantities under modern manufacturing methods. Any failure, therefore, to co-ordinate closely the work of the industrial research department with that of the manufacturing department would result in considerable delays and inconveniences and great monetary loss.

For purposes of administration and the more efficient carrying on of the work, the laboratory is divided loosely into a number of principal divisions, each concerned with some general phase of

Digitized by Google

the industrial research problems peculiar to the telephone and telegraph industry. Thus we have the chemical laboratory, dealing with the class of problems its name indicates; the transmission laboratory, dealing with those researches which are peculiarly involved with telephone transmitters, receivers and the efficient transmission of speech and telegraph currents; the fundamental physical research laboratory, which deals with the broader physical problems of the industry; the general physical laboratory, which deals with the more specific and immediate problems; the manual and machine switching circuit laboratories, which deal with those problems peculiar to the complicated networks which form such an integral part of modern communication systems; and finally, the various telegraph, mechanical and metallurgical laboratories, which deal with specific problems in other spheres of the work. All of these various laboratories are organized to work in the closest harmony and without unnecessary duplication. Very frequently the solution of some research problem involves the co-operation of three or four of the groups, each group handling the particular element of the problem for which its personnel and equipment particularly adapts it. Very frequently also problems arise which necessitate the formation of a special group selected from the various parts of the organization, with particular reference to the work in hand—this group being disbanded on the completion, or re-organized as the work progresses.

As indicated above, the laboratories of the Western Electric Company handle the physical, chemical and mechanical researches for the entire Bell System. In large measure these problems are those formulated as a result of the analytical researches of the first group noted above, namely, that under the immediate supervision of the Chief Engineer of the System. In the carrying on of this work with a staff of expert research investigators, many collateral problems arise. These problems, after preliminary investigation, are discussed with and studied by the members of the first group and if found to be of essential value in the art of communication they are put in the way of full and proper solution.

In conclusion, and judging the future by the evidence of the recent past, it seems clear that our industrial research problems are destined to grow enormously, provided an adequate supply of capable and highly trained investigators can be secured. This, and this alone, seems to mark the only practical limitation

Digitized by Google

to the size of our research organizations, since experience has shown that where the proper type of trained mind can be applied the financial results invariably return many times the cost of the research. To secure the necessary men, those charged with the direction of industrial research must look to the universities and higher technical schools. We must see that in our zeal to obtain immediate results we do not jeopardize our future by taking from the institutions the instructors and research men who can be of more service to the industries of the countries in their academic pursuits than they could be in industrial occupations.

Digitized by Google

Digitized by Google

Presented by publication only.

Copyright, 1917. By A. I. E. E.
(Subject to final revision for the Transactions)

ANNUAL LOAD RELIEF MAP, PEAK LOAD AND LOAD FACTOR ANALYSIS

BY WM. LE ROY ROBERTSON

ABSTRACT OF PAPER

Description of the annual load relief map which is a device for visualizing the entire yearly load of central stations.

Review of load characteristics, as exemplified by the annual load relief map.

Notes on daylight saving relative to the decreasing of peak load, and improvement in load factor.

Analysis of load factors as applied to "base" and "top" loads demonstrating the large amount of idle capacity peculiar to central stations.

Annual load relief map valuable in the study and exemplification of all matters having to do with central station loads.

THE familiar daily load diagram is plotted by practically all electric light and power companies. The accumulation of these curves soon becomes a mere record, usually filed away in some manner and always available for reference, and for the study of load conditions. When considering the load throughout the year it is difficult to obtain a comprehensive idea of the whole since it is necessary to glance separately at the greater portion of 365 sheets. Such a record locks up a desired vision in confusion.

The Annual Load Relief Map is a device for visualizing the entire load of the year. Each daily load diagram is marked off on card board and cut out. The cards are stacked up in proper daily sequence, mounted and provided with graduations for kilowatts, hours of the day and months of the year, all properly arranged. The annual load relief map is illustrated in Figs. 1, 2, and 7, showing the Philadelphia load during the year 1916.

Day Load. A distinctive feature brought out by the annual load relief map is the contour of the day load which is consistently uniform throughout the year, always picking up between 7:00 to 8:00 a. m., having a valley at noon and then falling off punctually at about 5:00 p. m. This stands out clearly on the annual load relief map Fig. 2; and especially well, if one will imagine the absence of the night load where it overlaps the day load at

NOTE: Written discussion of this paper is invited.

Digitized by Google

5:00 p. m. The day load corresponds closely to the regular average working day.

Night Load. The night load which picks up rapidly at 8:00 p. m. in mid-summer, and at about 4:30 p. m. to 5:00 p. m. in winter, corresponds closely to the lighting load. It depends absolutely upon the hour of sunset for its beginning and falls off rapidly, shortly after reaching its peak value. After midnight, it settles down to a low value and drops off almost entirely when the street lighting goes off near sunrise. In summer a deep valley will be seen in the morning, (Fig. 2) between the "fall-off" of the night load and the beginning of the day load, while in winter the loads overlap in the morning, filling up this valley.

Peaks. During the summer months there are three distinct peaks—one occurring about 8:00 a. m.; one about 5:00 p.m.; and

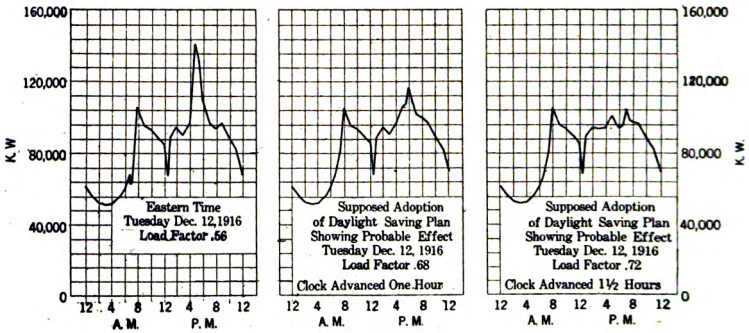


FIG. 3

the third about 8:00 p. m. With the approaching fall and winter months, and as the sun sets earlier each day, the 8:00 p. m. peak moves back toward the 5:00 p. m. peak and near the end of September the two peaks overlap, giving a combined peak greatly exceeding any other peak, which rapidly increases in height until the middle or latter part of December, when it becomes the greatest peak of the year. As the spring months approach the combined peak diminishes and finally near the end of March, disintegrates, forming again the two separate peaks. While the above is a well known fact, the annual load relief map presents the changing condition in a most striking manner.

Daylight Saving. During the past year or more, twelve European countries have adopted the plan of setting the clock one hour ahead during the summer months, in order to utilize a greater amount of daylight. Nova Scotia on this continent

Digitized by Google

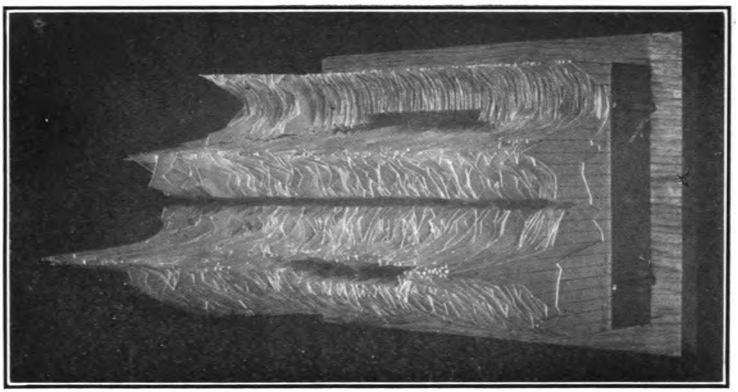


FIG. 2 [ROBERTSON]

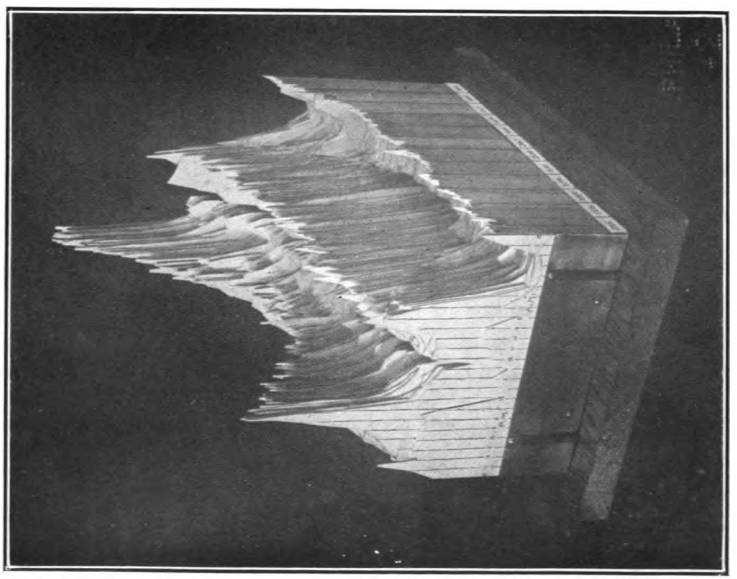


FIG. 1

Digitized by Google

Digitized by Google

has also adopted the plan. The cities of Detroit and Cleveland have practically accomplished the same thing by adopting Eastern Standard Time; and, further, the Committee on Daylight Saving of the Chamber of Commerce of the United States, in its report of February 1, 1917, recommended that Congress

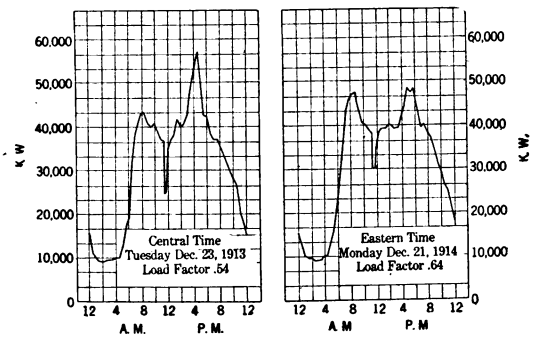


FIG. 4

adopt the plan throughout the United States—advancing the clock one hour throughout the year; and, as an alternative plan, advancing the clock one hour during summer only.

The annual load relief map will be found useful in conjunction with the study of the effect of daylight saving on peak loads.

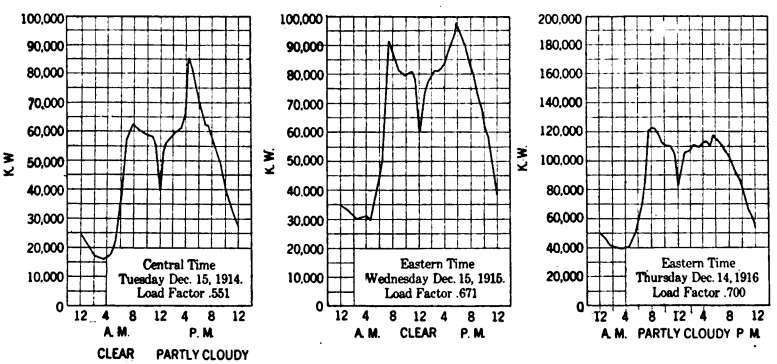


FIG. 5

Advancing the clock will have the same effect as shifting the day load back from the night load. Looking at Fig. 2, it will be seen that by shifting back the day load the valley between the 5:00 p. m. and 8:00 p. m. peaks will extend over a longer period during the summer; and if shifted back sufficiently, this valley will ex-

Digitized by Google

tend over the entire year, thus causing the big peak to disintegrate into the two separate peaks, eliminating entirely the big peak.

In order to entirely eliminate the big peak in Philadelphia, it is estimated that the clock should be set forward one and one-half hours. Fig. 3 illustrates what might have been the effect on the peak load in Philadelphia, had daylight saving been adopted during 1916. It should be understood, however, that these curves are merely a rough prediction, as it would be impossible to attempt to forecast the actual result.

The shifting back of the day load would also cause it to overlap the early morning load to a greater extent. This would increase the morning peak at 8:00 a. m.; but as the morning load is small, the increase would not be great. However, should winter office hours begin before daylight then the morning peak would obtain greater proportion.

Fig. 4 shows the effect of daylight saving on peak loads in Cleveland, while Fig. 5 shows the effect in Detroit. Cleveland's peak has greatly reduced, and it will be noted that the load factor has materially improved. In Detroit, it is understood that the radical change in the peak load has also been effected by other conditions than that of adopting Eastern Standard Time, *i.e.*, the load has greatly increased and all gem lamps have been changed over to Mazda's, during this period. The load curves given in Figs. 4 and 5 were furnished through the courtesy of the Cleveland Electric Illuminating Co. and the Detroit Edison Company, respectively.

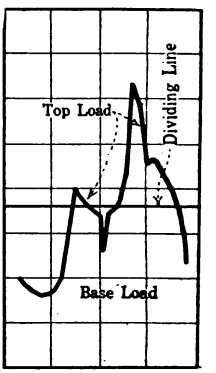


FIG. 6

Base and Top Loads—Load Factors. The total load on any central station may be divided into two sections as follows: Base load; top load. The sum of which equals the annual peak load, and the dividing line being a matter of judgment, as illustrated in Fig. 6.

After assuming any dividing line between the base and the top sections of the load, the annual load factor for the base section and the annual load factor for the top section may be computed from the 365 daily load curves covering the year in question. For a given annual load factor of the total load, the computed load factors of the base and top sections will not vary greatly between various central stations, as all central stations have very

Digitized by Google

similar load diagrams and considerable variation in the individual load diagram may take place before the load factors are affected.

Table I gives load factors of the base and top sections of the load, corresponding to a number of selected dividing lines, and repeated for several annual load factors of the total load. The

TABLE I

LOAD FACTORS OF VARIOUS BASE AND TOP LOADS

Dividing line between base and top loads			30% load factor of total load (annual)		40% load factor of total load (annual)	
Base load in per cent.	Top load in per cent.	Total load in per cent.	Annual load factor of the base load	Annual load factor of the top load	Annual load factor of the base load	Annual load factor of the top load
100	0	100	30%	0 %	40%	0 %
80	20	100	37%	¼ %	49%	½ %
60	40	100	50%	1 %	64%	2 %
50	50	100	58%	2 %	74%	6 %
40	60	100	69%	5 %	82%	11 %
20	80	100	91%	14 %	97%	26 %
0	100	100	100%	30 %	100%	40 %

Dividing line between base and top loads			50% load factor of total load (annual		60% load factor of total load (annual)	
Base load in per cent.	Top load in per cent.	Total load in per cent.	Annual load factor of the base load	Annual load factor of the top load	Annual load factor of the base load	Annual load factor of the top load
100	0	100	50%	0%	60%	0%
80	20	100	61%	1%	71%	5%
60	40	100	76%	9%	86%	19%
50	50	100	85%	15%	92%	27%
40	60	100	93%	22%	97%	35%
20	80	100	99%	38%	100%	50%
0	100	100	100%	50%	100%	60%

data in this table are presented here through the courtesy of L. B. Stillwell, Consulting Engineers, New York, from whom the information was obtained.

The results in Table I are most illuminating. Take for instance the case of a central station having an annual load factor

Digitized by Google

of 40 per cent, it will be noted from the table that there is 50 per cent of the load, *i.e.*, top load which has an annual load factor of only 6 per cent, or stating this in a more practical sense—there is equipment in such a plant sufficient in capacity to carry 50 per cent of the maximum load which is idle 94 per cent of the time. Take another case of a company with a 30 per cent annual load factor: there is equipment in this plant sufficient in capacity to carry 60 per cent of the maximum load which is idle 95 per cent of the time. Any one having difficulty in conceiving these facts will find that the annual load relief map will aid in making them clear. Here the "dividing line" becomes a dividing plane, and it will be noted that the top section of the load above the plane for the entire year is indeed very small when the dividing plane is at 50 per cent of the maximum load or above.

By examining the annual load relief map, it will be noted that the empty void between the contour of the load and a horizontal plane placed at the tip of the highest peak represents the business that a central station can theoretically carry along with its present business without increasing its equipment. If the central station load factor is 33 per cent, then this void represents 200 per cent of the business already carried. In cutting out the cards of an annual load relief map, if the upper half of the card is saved and stacked up, the mass of cards will represent the additional business that could be carried in theory by a central station without increasing the capacity. Fig. 7 represents the upper part of the annual load relief map. Here it will be noted that all the Saturdays and Sundays were separated and stacked separately at one end, in order not to hide the effect of the week days.

After the author devised the annual load relief map, it was learned that Mr. H. A. Barre of the Pacific Light & Power Corporation of Los Angeles, California, has been making use of practically the same scheme for the past several years. In connection with certain analysis of the relative values of water power and steam reserve, Mr. Barre found use for such a device in order to explain to the banker's satisfaction how much power would be carried by the water power, and how much by the steam reserve. At first, he experimented with a cube of wood, sawing along the line of the daily and yearly contours of the load which were respectively laid out on the faces of the cube at right angles, and later he stacked up the cards. Fig. 8 is a photograph,

Digitized by Google

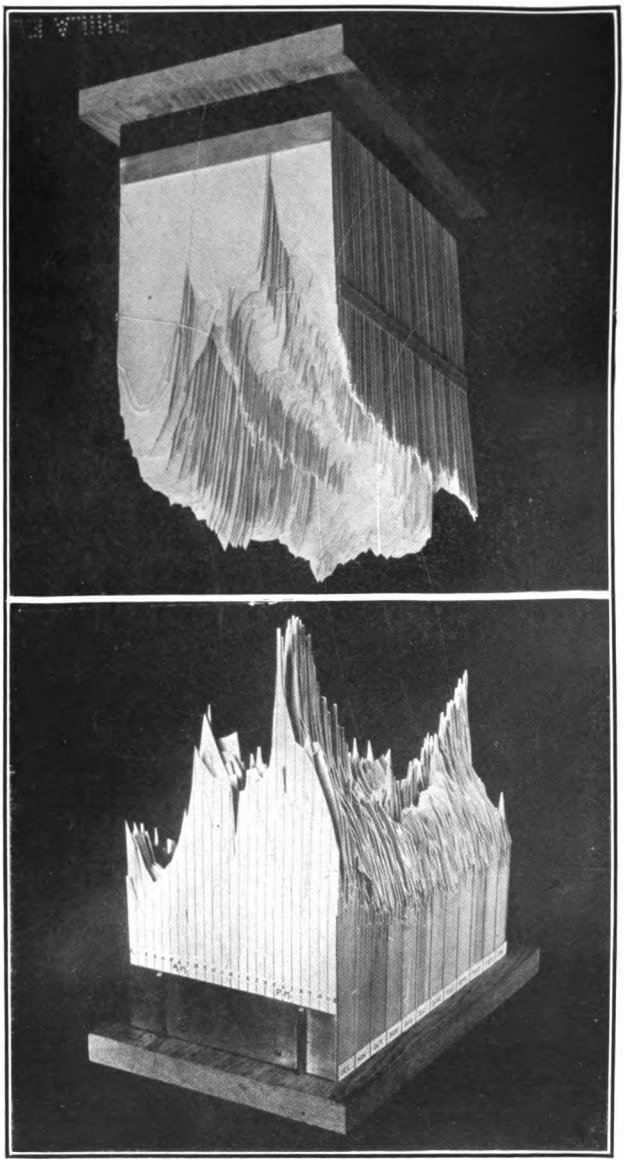


FIG. 7 [ROBERTSON]

Digitized by Google

Digitized by Google

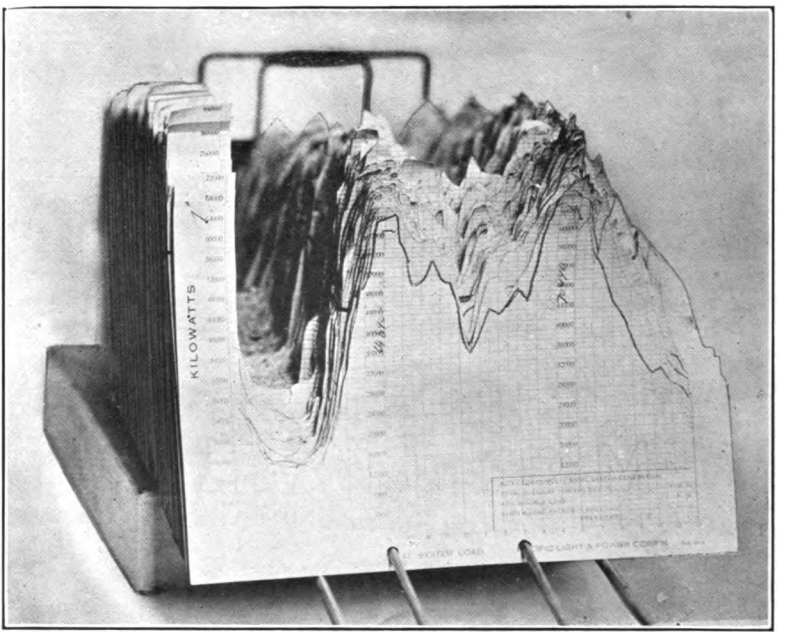


FIG. 8 [ROBERTSON]

Digitized by Google

Digitized by Google

which was very kindly furnished by Mr. Barre, showing his plan. Each diagram is cut out in paper and placed in the file—5 years would be 7 to 8 in. (17.7 to 20.3 cm.) thick.

It might be suggested that commercial men may find much interest in following up the load growth from year to year upon the annual load relief map, and again the device may be useful as an aid in explaining various problems in connection with rates and investment before public service commissions.

Digitized by Google

Digitized by Google

To be presented at a meeting of the San Francisco Section of the American Institute of Electrical Engineers, San Francisco, Cal., January 25, 1918.

Copyright 1917. By A. I. E. E.

(*Subject to final revision for the Transactions.*)

CORONA TESTS AT HIGH ALTITUDE

BY B. F. JAKOBSEN

ABSTRACT OF PAPER

This paper describes some corona tests which were made in Peru on a 70-mile transmission line located at an average altitude of 13,500 feet. The voltages range from 40,000 to about 72,000.

The method employed in the tests is described and the calculations are given. The corona losses were found by subtracting the core and copper losses of the transformers and the line copper losses due to the line charging currents from the total loss measured. Core-loss tests were made on the transformers in order to check these against the shop tests. The highest voltage experimented with was 72,300 when a corona loss of 153 kw. was found, or a little over two kw. per mile of line.

The results are compared to "Peek's law" and a wide divergence found, amounting to over 800 per cent at about 66,000 volts and a loss of 58 kw.

Close correspondence is found between these tests and those made by Faccioli on the Shoshone-Leadville line, and the equation of the loss-voltage curve obtained is the same as was established by Faccioli, and shows this relation to be logarithmic and not quadratic for the voltage range investigated.

It is shown that the results are in good agreement with the formulas deduced by Professor Ryan from extensive laboratory tests.

Finally test data are given for a test made during rainy weather and this shows no appreciable difference from tests made during fair weather.

INTRODUCTION BY FRANK G. BAUM

There has been installed in Peru under the writer's direction a hydroelectric plant having about 120 mi. (193.1 km.) of transmission line, running from 12,000 to 14,000 ft. (3,657.6 to 4,267.2 m.) elevation, with most of the line at about 13,000 ft. (3,962.4 m.).

I considered this an excellent opportunity to make some actual corona tests at high altitude, as these would be of value to the profession. The results are shown in the report of a test on 68.4 mi. (110 km.) of three-phase line by Mr. B. F. Jakobsen, electrical engineer.

The results are encouraging, in that the actual losses are less than expected, and as this fact influences to some extent

Manuscript of this paper was received October 3, 1917.

Digitized by Google

the size of wire to be chosen, it is seen that the matter is of practical importance to the electrical profession.

Probably there is no line which has more severe lightning conditions than this one. And no doubt the high altitude and consequent light air pressure allows atmospheric discharges that would not occur at lower altitudes for the same cloud potential conditions, for the same reasons that we have corona at high altitude for less voltage than at low altitude.

While not directly related to corona it may be of interest to know that the transmission has been freer from lightning troubles than anticipated. One line about 90 mi. (144.8 km.) long is operated at 44,000 volts, Y grounded, (this line was formerly delta operated as mentioned in the test report) and another line about 20 mi. (32.1 km.) long is operated 25,000 volts, delta ungrounded. Aluminum lightning arresters and horn gaps are used. The Y line is more free from lightning troubles than the delta line, but the amount of trouble on either line has been almost negligible.

AT THE request of Mr. Frank G. Baum of San Francisco some corona tests were made in April 1914 in Peru, South America on a newly constructed transmission line. The tests were made on that part of the line which runs from the power house at Oroya (12,250 ft. or 3,733.8 m. elevation) to the smelter substation at La Fundicion (about 14,000 ft. elevation), see profile Fig. 1.

Several tests were made at frequencies near normal (60 cycles) and as these tests gave practically identical results, only two are given herewith, one for fair weather and one for rainy weather.

A frequency of 61.1 cycles was chosen as this was the highest at which the water-wheels could be operated under control of their governors.

Power Plant Data. At the power plant there are three 5000-h.p. generating units, each consisting of two impulse-type waterwheels direct connected to one 60-cycle, 2300-volt, 3-phase star-connected, ungrounded-neutral generator. For each generating unit there is provided three 1000-kv-a. 2300—55,000-volt transformers, connected in delta on both sides. All instrument transformers were in the 2300-volt leads between the generators and the transformers.

Digitized by Google

Transmission Line Data. The line consists of two three-phase circuits of No. 1 B. & S. stranded copper wire and a grounded steel cable ¼ in. (6.3 mm.) diameter, carried on one steel-pole line and arranged as shown in Fig. 2. Each circuit was given two complete transpositions between Oroya and La Fundicion and the distance from Oroya to La Fundicion along the line is 68.4 mi. (110 km.) and the normal operating voltage is 44,000.

The line constants[1] are as follows:

Resistance of one wire, 68.4 mi. at 20 deg. cent....	46.2
Reactance of one wire, 68.4 mi. at 61.1 cycles.....	54.6
Impedance of one wire, 68.4 mi.....	71.6
Susceptance of one wire, 68.4 mi. and 61.1 cycles..	387×10^{-6}

One unit only was used in these tests, but during all the tests about 2500 kw. at a power factor of about 0.6[2] was carried on

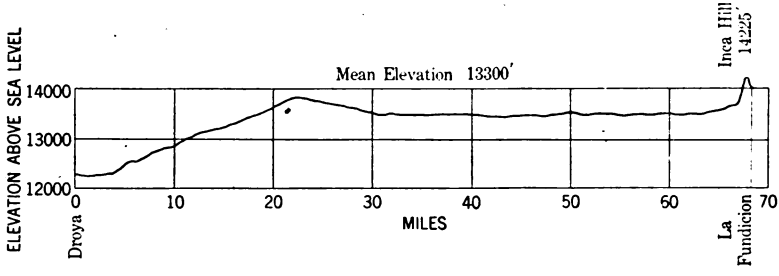


FIG. 1—PROFILE OF LINE, OROYA TO LA FUNDICION

one of the other units and transmitted to the smelter substation over one of the two circuits.

Transformer Data. The name plates of the transformers had been lost and the shop-test data could therefore not be applied to each transformer. The resistance of the three high-tension windings in series was measured at 21 deg. cent. with a Wheatstone bridge, and the average taken. The resistance of the low-tension windings was taken as the average of the nine transformers from the shop report, as the Wheatstone bridge was not adaptable for measuring such small resistances. The impedance drop was assumed equal to the average for the nine transformers taken from the shop-test report, as it could not readily be measured with the available equipment. The average im-

1. TRANS., A. I. E. E. 1911 Vol. XXX, Part III, p. 2264.

2. The 1500-h.p. synchronous motor provided at the smelter substation to improve the power factor was not ready for operation when the tests were made.

Digitized by Google

pedance drop at 60 cycles is 4.105 per cent; assuming 2.105 per cent for the high-tension winding and 2.0 per cent for the low-tension winding, the transformer constants at 21 deg. cent. and 61.1 cycles, with 2300—55,000-volt connection and expressed on the high-tension side, are: High-tension winding:

$$R = 11.45; \quad X = 62.6, \text{ and } Z = 63.6;$$

Low-tension winding:

$$r = 12.5; \quad x = 56.65, \text{ and } z = 57.95$$

Meters and Instrument Transformers. The instruments used were standard switchboard instruments furnished with the Oroyo switchboard and the current transformers for the ammeter and the indicating and integrating wattmeters were 1200-5 amperes

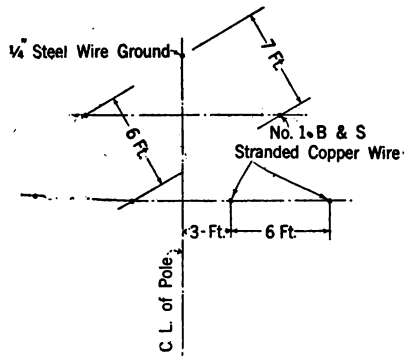


FIG. 2—ARRANGEMENT OF WIRES ON TRANSMISSION LINE.

ratio. In order to augment the readings on these instruments, 300-5-ampere current transformers were connected in series with the 1200-5-ampere current transformers on the 2300-volt side and in parallel on the instrument side, thus increasing the readings in proportion of ·1 to 5. No power factor indicator was available.

Method of Tests. Before starting the corona tests, a test was made to determine the transformer exciting current and the core loss for the range of voltages and frequencies to be employed. In this test the generator current (equals $\sqrt{3}$ times transformer exciting current), generator voltage, kilowatts and frequency were measured.

For the corona tests these same quantities were measured and the corona loss obtained by subtracting the transformer core

Digitized by Google

losses, transformer copper losses and the line copper loss due to the charging current from the total generator output.

Calculations. Fig. 3 shows the diagram of connections and Fig. 4 the corresponding vector diagram, wherein:

E_g = generator voltage
E_t = transformer core voltage
E_L = line voltage at generator end
I_{ch} = charging current per wire
I_{co} = corona current (equivalent sine value)
I_L = line current per wire
I_t = transformer exciting current
I_g = generator current = $\sqrt{3}\, I_t$

all expressed on the high-tension side and all voltages between wires.

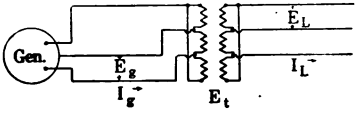


FIG. 3

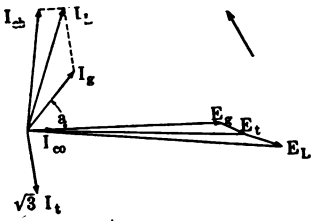


FIG. 4

The current I_{co} due to corona is quite small in all these tests; at 72.3 kv. the corona loss is 153 kw. and the equivalent sine current[3] in phase with the voltage is

$$I_{co} = 153 \div 1.73 \times 72.3 = 1.22 \text{ amperes}$$

The corona current has therefore been entirely neglected in the computations.

Referring to the vector diagram Fig. 4, the line charging current is very nearly 90 deg. out of phase with the voltage[4] and for voltages above 50 kv. the generator current due

3. See oscillographs by Bennett, A.I.E.E., TRANS., Vol. 32, p. 1787 and cyclogram by Prof. Ryan, p. 1825 and remarks under 8 on p. 1827, Vol. 32.

4. At 72.3 kv. the charging current is 16.3 amperes and the line loss for 3 wires $\frac{16.3^2 \times 46.2}{1000}$ = 12.2 kw. and the resulting power factor 0.0975 and angle = 84° 20′. For smaller voltages this power factor is still smaller.

Digitized by Google

to the transformer exciting currents is very nearly 90 deg. out of phase with the generator voltage, see Fig. 7. The generator current during the corona test is also nearly 90 deg. out of phase with the generator voltage (the current leads), except for the higher voltages when the generator current is small, (see Fig. 8) as the line current and $\sqrt{3}$ times the transformer exciting current more nearly balance each other. Since also the transformer reactances are several times larger than the corresponding resistances, and the drop due to the transformer resistances, with the currents involved, is comparatively very small and at right angles to the generator voltage, it follows that the vector relations shown in Fig. 5, may be substituted for those shown in Fig. 4. All this simplifies the calculations very materially without introducing any appreciable errors, as far as current and voltage calculations are concerned.

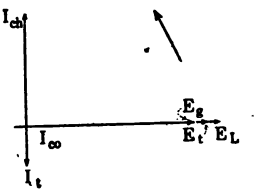


FIG 5

Formulas. Line. Neglecting the voltage component due to the charging current and the line resistance, as this component is very nearly 90 deg. out of phase with the line voltage and comparatively very small. Let

E_r = voltage at receiver end, of line when the current at receiver end is zero, then[5]

$$I_{ch} = \frac{E_r}{\sqrt{3}}\, b \left(1 - \frac{b\,x}{6}\right) \text{ and } E_r = \frac{E_L}{1 - \frac{b\,x}{2}} = 1.0106\, E_L \qquad (1)$$

b = line susceptance for one wire and voltage to neutral,
x = line reactance for one wire;

Combining:

$$I_{ch} = \frac{E_L \times b}{\sqrt{3}\left(1 - \frac{b\,x}{2}\right)}\left(1 - \frac{b\,x}{6}\right)$$

$$I_{ch} = 0.226\, E_L \text{ amperes.} \qquad (2)$$

Line Loss Due to Charging Current. Assuming the charging current per unit length of line to be constant, or in other words,

5. Hagood, A. I. E. E., TRANS., Vol. 32, p. 868.

Digitized by Google

that the current on the line is, at any point, directly proportional to its distance from the receiver end of the line, then;

$i_{ch} = I_{ch} \frac{s}{S}$, where i_{ch} = charging current s miles from the receiver end of the line and
S = total length of line.
I_{ch} = line charging current at generator end.

$$\text{Loss on three wires} = 3 \int_0^S I_{ch}^2 \frac{s^2}{S^2} \frac{r}{S} \, d\, s = I_{ch}^2 \times r \qquad (3)$$

$$= \frac{2.36 \times E_L^2}{1000} \quad \text{kw.}$$

Voltage rise in low-tension transformer windings:

$$E_t - E_g = I_g \times x \div 1.73 = 0.0327\, I_g \qquad (4)$$

Voltage rise in high-tension transformer windings:

$$E_L - E_t = I_{ch} X \div 1.73 = 0.00816\, E_t \qquad (5)$$

In (4) and (5) all voltages are in kilovolts and for leading currents.

Loss in low-tension transformer windings:

$$\left(\frac{I_g}{\sqrt{3}}\right)^2 \times \frac{3\, r}{1000} = 0.0125\, I_g^2 \quad \text{kw.} \qquad (6)$$

Loss in high-tension transformer windings:

$$\frac{I_{ch}}{\sqrt{3}} \times \frac{3\, r}{1000} = 0.585\, E_L^2 \div 1000 \quad \text{kw.} \qquad (7)$$

Combining (3) and (7), the loss on the line and in the high-tension windings together is

$$2.945\, E_L^2 \div 1000 \quad \text{kw.} \qquad (8)$$

Core Loss Test. The result of this test is plotted in Fig. 7; the relation between the integrating wattmeter readings and the indicating wattmeter readings is plotted in Fig. 6. The indicating wattmeter readings have been corrected as per curve *B* Fig. 6 for use in Fig. 7. The frequency was 61.1 cycles.

Digitized by Google

Remarks on Wattmeter Accuracy. As already stated two current transformers with different ratios were in series on the 2300-volt side and in parallel on the instrument side. Full rated current on the 1200-5 ampere current transformers is about 50 amperes (on the high-tension side) and 12.5 amperes for the 300-5 ampere current transformers.

At 55 kv. and 61.1 cycles, the core loss for three transformers is (Fig. 7) 24.5 kw.; the exciting current times $\sqrt{3}$ is 2.65 amperes.

Three times the average core loss of the nine transformers at 60 cycles is according to the shop test report 21.94 and the average for the exciting current times $\sqrt{3}$ is 2.75 amperes. The core loss for the nine transformers varies between a minimum

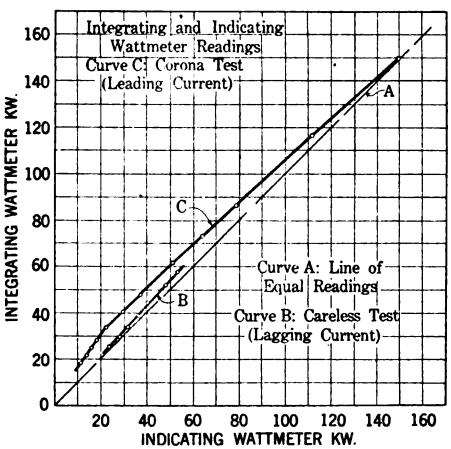


FIG. 6

of 6.9 kw. a maximum of 7.81 kw., while $\sqrt{3}$ times the exciting current varies from 2.16 to 3.41 amperes.

The influence of the frequency upon the core loss may be estimated roughly, as follows:

$$\left.\begin{aligned} \text{voltage} &= e = c\,f\,B \\ \text{core loss} &= p\,k\,f\,B^{3.34} \end{aligned}\right\} \qquad (9)$$

where,

c and k are constants,

f = frequency,

B = magnetic flux per unit area of core, and

the exponent 3.34 is calculated for values between 50 kv. and 60 kv. from Fig. 7.

Digitized by Google

From (**9**) it is found, that the core loss at 61.1 cycles is about 96.5 per cent of the core loss at 60 cycles; the core loss as measured was 24.5 kw. at 61.1 cycles and would accordingly have been 25.4 kw. at 60 cycles. The shop tests[6] give for the three transformers with highest core loss only 22.62 kw. or about 11 per cent less than found in the above test.

This discrepancy may be due solely to the instruments and their transformers and in that case would indicate a correction angle of about 40 min. and that the resultant secondary current of the current transformers lead the primary current, *i.e.*, the generator current.[7] In this case, we could expect wattmeter readings about 11 per cent low for the same current and voltage, but a leading current.

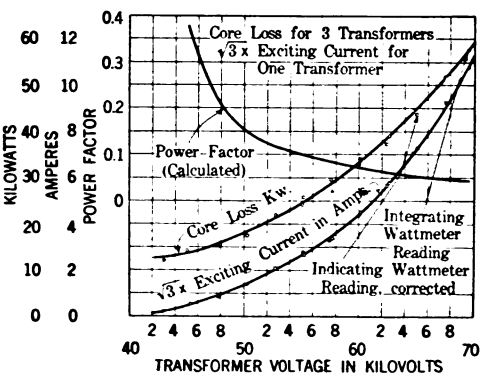


FIG. 7

However, the values for core losses given in the shop reports are for a sine form of the e.m.f. wave. When operating on open circuit, the generator e.m.f. wave is practically a sine curve, but when the transformers are connected to the generator and with the star-delta-delta connection used here, it is likely that a fifth harmonic in excess of the amount demanded by the hysteresis cycle[8] appears in the transformer and generator currents, causing a fifth harmonic to appear in the e.m.f. waves with a corresponding flattening of the voltage crest[9] and a corres-

6. The shop reports give (60 cycle, 55,000 volt):—7.07; 7.20; 6.90; 7.39; 7.40; 7.81; 7.30; 7.41 and 7.325 kw. respectively for the nine transformers in the Oroya power plant.

7. Robinson, A. I. E. E., TRANS., Vol. 28, page 1005.

8. Janet, Lecons d'electrotechnique générale, 2 Ed., Vol. 2 p. 191.

9. Curtis, A.I.E.E., TRANS., Vol. 33, p. 1273 and Figs. 10, 11 and 12.

Digitized by Google

ponding increase of core loss for the same effective voltage. If, as a limiting value, the e.m.f. wave form was rectangular, the core loss would be about $1.11^{3.34}$ or 51 per cent in excess of the core loss for a sine wave with the same effective voltage and same frequency.[10]

TABLE I.—CORONA TEST. 61.1 CYCLES.
(Values given for high-tension side of transformers.)

Generator voltage in kv.	Generator current in amperes	Indicating wattmeter kw.	Integrating wattmeter kw.
40.5	9.2	11	18.7
43.0	9.61	14	21.6
45.5	10.0	16	
45.3	9.97	16	24.9
47.8	10.24	18	
47.3	10.2	18	28.2
50.1	10.49	22	
50.0	10.48	22	33.5
52.9	10.58	29	
52.8	10.58	30	40.5
55.1	10.5	37	
55.1	10.5	37	47.9
57.9	10.2	51	
60.0	9.71	64	61.0
62.1	9.1	78	73.2
64.5	7.95	108	86.5
66.9	6.7	140	
69.3	5.1	183	
71.6	3.6	237	
69.3	5.15	177	
66.9	6.98	135	
64.5	8.12	105	
62.1	9.24	77	
59.7	9.81	64	
57.2	10.29	50	
55.1	10.24	41	
52.6	10.58	34	
50.3	10.5	28	
64.6	7.7	111	126
67.2	6.31	149	149

The integrating wattmeter readings were calculated from the formula: Kw. = $11{,}520\ R/T$ where R is the revolutions of aluminum disk for T seconds. The readings were taken for one revolution of disk and the time, varied from 123 to 15.4 seconds and was taken by a stop watch.

All readings are actual readings, so that the ammeter and wattmeter readings are to be multiplied by 1/5 and the voltmeter reading by 20 in order to obtain actual values.

10. Kapp, Transformatoren für Wechselstrom and Drehstrom, 2 Ed. [p. 23.

Digitized by Google

TABLE II*.—CORONA TEST. 61.1 CYCLES

	Generator voltmeter volts	Generator ammeter amperes	Indicating wattmeter readings kw.	Integrating wattmeter readings seconds
1	84.8	1100	55	123
2	90.0	1150	70	106
3	95.3	1195	80	92.2
	94.9	1192	80	
4	100.0	1225	90	81.5
	98.9	1220	90	
5	105.0	1254	110	68.5
	104.7	1252	110	
6	110.9	1265	145	56.6
	110.8	1265	150	
7	115.5	1258	185	48.0
	115.4	1258	185	
8	121.2	1220	255	37.6
9	125.7	1163	320	31.4
10	130.0	1038	390	26.6
11	135.0	950	540	
12	140.0	800	700	
13	145.0	610	915	
14	150.0	430	1185	
15	145.0	615	885	
16	140.0	834	675	
17	135.0	970	525	
18	130.0	1105	385	
19	125.0	1175	320	
20	119.8	1230	250	
21	115.5	1255	205	
22	110.3	1265	170	
23	105.3	1257	140	
24	135.5	920	555	19.8
25	140.8	755	745	15.4

*Measurements as actually taken and from which Table I was derived.

From the above, the values plotted in Figs. 8 and 9 were calculated by the formulas given previously.

As a check on the correctness of the measurements, the calculated charging current is shown in Fig. 8 as the straight line and the points are the measured generator currents plus $\sqrt{3}$ times the transformer exciting currents taken from Fig. 7 for the corresponding voltages. The agreement between the measured values and the calculated currents is quite good.

Curve *A* in Fig. 9 is the total loss as measured above; the integrating-meter readings have been taken and the indicating-wattmeter readings corrected according to curve in Fig. 6, where the integrating and indicating-wattmeter readings are plotted against each other.

Digitized by Google

ponding increase of core loss for the same effective voltage. If, as a limiting value, the e.m.f. wave form was rectangular, the core loss would be about $1.11^{3.34}$ or 51 per cent in excess of the core loss for a sine wave with the same effective voltage and same frequency.[10]

TABLE I.—CORONA TEST. 61.1 CYCLES.
(Values given for high-tension side of transformers.)

Generator voltage in kv.	Generator current in amperes	Indicating wattmeter kw.	Integrating wattmeter kw.
40.5	9.2	11	18.7
43.0	9.61	14	21.6
45.5	10.0	16	
45.3	9.97	16	24.9
47.8	10.24	18	
47.3	10.2	18	28.2
50.1	10.49	22	
50.0	10.48	22	33.5
52.9	10.58	29	
52.8	10.58	30	40.5
55.1	10.5	37	
55.1	10.5	37	47.9
57.9	10.2	51	
60.0	9.71	64	61.0
62.1	9.1	78	73.2
64.5	7.95	108	86.5
66.9	6.7	140	
69.3	5.1	183	
71.6	3.6	237	
69.3	5.15	177	
66.9	6.98	135	
64.5	8.12	105	
62.1	9.24	77	
59.7	9.81	64	
57.2	10.29	50	
55.1	10.24	41	
52.6	10.58	34	
50.3	10.5	28	
64.6	7.7	111	126
67.2	6.31	149	149

The integrating wattmeter readings were calculated from the formula: Kw. = $11{,}520\,R/T$ where R is the revolutions of aluminum disk for T seconds. The readings were taken for one revolution of disk and the time, varied from 123 to 15.4 seconds and was taken by a stop watch.

All readings are actual readings, so that the ammeter and wattmeter readings are to be multiplied by 1/5 and the voltmeter reading by 20 in order to obtain actual values.

10. Kapp, Transformatoren für Wechselstrom and Drehstrom, 2 Ed. p. 23.

Digitized by Google

TABLE II*.—CORONA TEST. 61.1 CYCLES

	Generator voltmeter volts	Generator ammeter amperes	Indicating wattmeter readings kw.	Integrating wattmeter readings seconds
1	84.8	1100	55	123
2	90.0	1150	70	106
3	95.3	1195	80	92.2
	94.9	1192	80	
4	100.0	1225	90	81.5
	98.9	1220	90	
5	105.0	1254	110	68.5
	104.7	1252	110	
6	110.9	1265	145	56.6
	110.8	1265	150	
7	115.5	1258	185	48.0
	115.4	1258	185	
8	121.2	1220	255	37.6
9	125.7	1163	320	31.4
10	130.0	1038	390	26.6
11	135.0	950	540	
12	140.0	800	700	
13	145.0	610	915	
14	150.0	430	1185	
15	145.0	615	885	
16	140.0	834	675	
17	135.0	970	525	
18	130.0	1105	385	
19	125.0	1175	320	
20	119.8	1230	250	
21	115.5	1255	205	
22	110.3	1265	170	
23	105.3	1257	140	
24	135.5	920	555	19.8
25	140.8	755	745	15.4

*Measurements as actually taken and from which Table I was derived.

From the above, the values plotted in Figs. 8 and 9 were calculated by the formulas given previously.

As a check on the correctness of the measurements, the calculated charging current is shown in Fig. 8 as the straight line and the points are the measured generator currents plus $\sqrt{3}$ times the transformer exciting currents taken from Fig. 7 for the corresponding voltages. The agreement between the measured values and the calculated currents is quite good.

Curve *A* in Fig. 9 is the total loss as measured above; the integrating-meter readings have been taken and the indicating-wattmeter readings corrected according to curve in Fig. 6, where the integrating and indicating-wattmeter readings are plotted against each other.

Digitized by Google

Curve B in Fig. 9 is the sum total of all the losses, calculated from the test and the given formulas. Curve C is the corona loss, the difference between curve A and B.

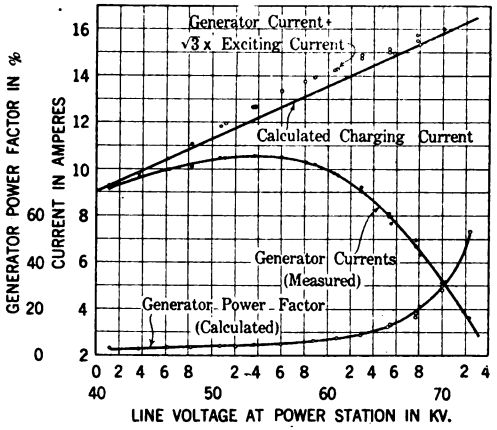

Generator Current + √3 x Exciting Current
Calculated Charging Current
Generator Currents (Measured)
Generator Power Factor (Calculated)
GENERATOR POWER FACTOR IN %
CURRENT IN AMPERES
LINE VOLTAGE AT POWER STATION IN KV.

FIG. 8

Comparison of Test with Published Formulas. A.—Peek's Law of Corona, A. I. E. E., Vol. 30, p. 1894, equation (**8**). $m_0 = 0.87$; $g_0 = 21.1$ kv. eff.; $r = 0.42$ cm.; $s = 183$ cm.; $b = 45.93$ (mean value); $t = 16.4$ deg. cent.; $\delta = 3.92 \times 45.93 \div (273 + 16.4) = 0.622$; distance = 110 km. E = voltage between wires in kv.; then for this line,

$$P = 1.78\,(E - 50.5)^2 \qquad \text{kw.} \quad (9)$$

Line kv.	Peek's law form. (9) kw.	Curve C Fig. 9 kw.	Ratio
50.5	0	6.0	
54	22	9.6	2.29
58	100	17.5	5.72
62	236	31.5	7.49
66	428	57.5	8.31
70	678	105.5	6.42
72.3	848	153.0	5.54

The original test data were submitted to Professor Ryan in June 1914 and Fig. 9 Curve A was made at that time by Professor Ryan. The close agreement between the two curves

Digitized by Google

suggested further analysis of the losses found on the Oroya line and these are given below.

Referring to Fig. 9 curve *A* Professor Ryan wrote:

"In Fig. 6, page 342 of the A. I. E. E., 1911, TRANSACTIONS Faccioli gives the corona losses found in fair weather on the 63-mi. transmission from Shoshone to Leadville of the Central Colorado Power Co. at an average elevation of 8500 ft. and a maximum of 12,000 ft. This line has a length of 102 km. while the Oroya-smelter line has a length of 110 km. The Shoshone line developed a corona loss of 51.5 kw. at 95.8 kv.; the Oroya line 55 kw. at 65.6 kv., *i. e.* one-half kilowatt per kilometer in each case. For the purpose of comparison, we may assume that corona

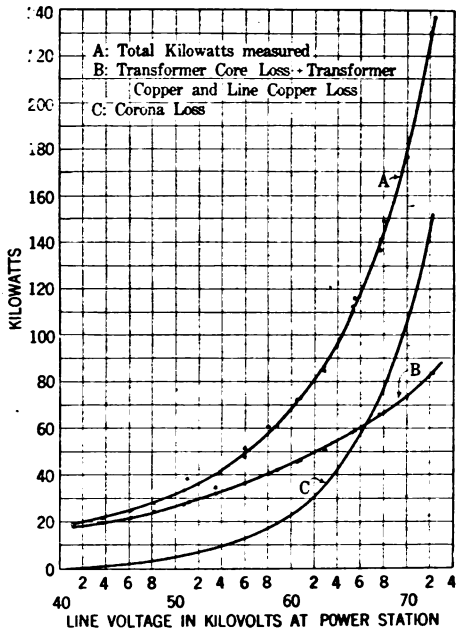


FIG. 9

was definitely started at this amount of loss, viz.: one-half kilowatt per kilometer of line. This is really about the only value in regard to corona formation that approaches some degree of definiteness when related to voltage, line capacity, barometer and temperature, aside from the fact that the amount of corona loss is largely dependent upon $(E - E')$ rather than E, wherein E' is the line voltage that produces a corona loss of one-half kilowatt per kilometer and E is any higher line voltage. It follows therefore, that the corona was started on the Shoshone line at 95.8 − 65.8 = 30 kv. higher than the Oroya line. Other things being equal, the amount of corona loss is due to the amount of voltage that exceeds corona starting voltage. Let us call such voltage that exceeds corona starting voltage, *Corona Voltage*. Then in Fig. 9-*A*:

Digitized by Google

I. Oroya-smelter transmission corona voltage and corona loss; length 110 km. average elevation 13,300 ft., maximum 13,800 ft.

II. Shoshone-Leadville transmission corona voltage and corona loss; length 102 km.; average elevation 8500 ft.; maximum 12,000 ft.

I have mounted also the corresponding total line voltages. In comparing the two curves, the differences in length of lines and in the elevations must be kept in mind. We know how to allow for the difference in length but we are not sure that we know exactly how to allow for the differences in altitude. Peek came to the conclusion that corona loss is inversely proportional to the density of the atmosphere. Such conclusion is reasonable. The corresponding composite factor for reducing the Shoshone-Leadville corona loss to a corona loss corresponding to the Oroya-smelter altitude, barometer and temperature, thus becomes 0.93.

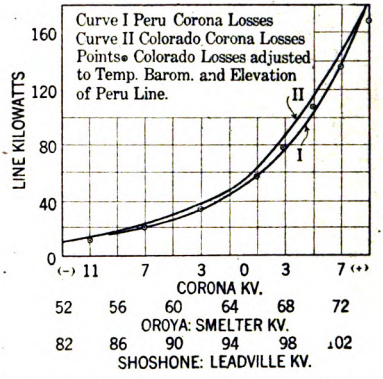


FIG. 9A—CURVE CHART FOR COMPARISON OF OROYA-SMELTER (PERU) AND SHOSHONE-DENVER (COLORADO) TRANSMISSION LINE CORONA LOSSES

Location of Line	Length km.	Average barom. cm.	Average temp. deg. cent.	Authority
Peru.....	110	45.9	16.4	Jakobsen report Apr. 27, 1914
Colorado.....	102	52.0	5.0 (Assumed)	Faccioli, TRANS. A. I. E. E., 1911

In Fig. 9-A, the points enclosed with small circles were located on corresponding ordinates of the Shoshone-Leadville corona loss curve by means of the proportional dividers set at 0.93. You will note that they are in close agreement with the corresponding Oroya-smelter-transmission corona-loss values. Some difference in the forms of the curves must exist because of the differences in the mountain profiles traversed by the corresponding lines. Then, to, the instruments must, inevitably, have been out by small amounts as instruments of the type that had to be employed usually are. Neither cause, however, is a basis for expecting much difference between the two curves."

Analysis of Oroya-Smelter Corona-Loss Curve. In Fig. 10 the square root of the corona loss, equal to $\sqrt{p}$, is plotted against the

Digitized by Google

line voltage. As this line is not a straight line, the loss curve is not quadratic. Assuming, however, that the loss curve from 69 kv. upwards is quadratic, we get[11] using the $\Sigma\,\Delta$ method:

$$p = 0.765\,(E - 58.23)^2 \quad \text{kw.} \quad (10)$$

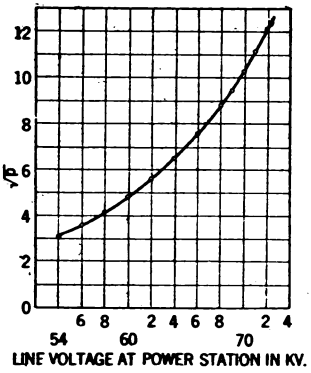


FIG. 10

Plotting the line voltage from 56 kv. upwards against the logarithm of the corona loss from Fig. 9, gives a straight line, and by the $\Sigma\,\Delta$ method is found:

$$p = \epsilon^{0.1525\,(E-39.2)} \quad \text{kw.} \quad (11)$$

$$\text{or } \log p = 0.0662\,E - 2.6$$

where ϵ = the base of the natural logarithms.

This equation holds good for the whole range and it is the same equation found by Faccoli,[12] partiicularly curve *B* Fig. 10.

The following shows the close agreement between the test and formula (11) above:

Line voltage kilovolts	Equation (11) kw.	Curve *C*. Fig. 9 kw.
44	2.1	1.5
46	2.6	2.5
48.	3.0	4.0
50	5.1	5.5
52	8.7	7.0
54	10.2	9.6
56	12.9	13.0
58	17.4	17.3
60	23.4	23.2
62	32.4	31.5
64	43.6	42.3
66	58.9	57.5
68	79.4	77.5
70	109.5	105.5
72	144.5	146.5
72.3	151.5	153.0

11.

Kilovolts	Fig. 9 kw.	kw.
69	90	9.48
70	105.5	10.26
71	124	11.13
72.3	153	12.37

12. $p = 9.5\,\epsilon^{(0.089\,E-9.75)}$. A. I. E. E., TRANS., Vol XXX p. 349.

Digitized by Google

B.—Prof. Ryan's formula, A. I. E. E., TRANS., Vol. 30, p. 64.

Equation (3) on p. 69, Vol. 30 gives the voltage at which the loss due to part corona is about equal to the loss due to convection, and this last named loss is given by the equation at the bottom of p. 67, Vol. 30, viz.:

Loss per 1000 ft. of single-phase line $= p = 2 \times f^2 \times E^2 \times 10^{-6}$ watts (12) where, f = frequency and E kilovolts between wires. For one wire therefore,

$$P = 4 \times f^2 \left(\frac{E}{2}\right)^2 \times 10^{-6} \text{ watts; and for three wires of} \qquad (12)$$

a three-phase circuit,

$$P = 4 \times f^2 \times E^2 \times 10^{-6} \quad \text{watts} \qquad (13)$$

For 61.1 cycles and 68.4 miles of three-phase line,

$$P = 5.48\, E^2 \quad \text{watts} \qquad (14)$$

The critical corona voltage is then, equation (3) p. 69, Vol. 30

$$E_{crit.} = 0.455 \times k \frac{17.9\, b}{459 + t} \frac{d + 2\, a}{C} \qquad (15)$$

where, C = 1.16 times capacity of 1000 ft. (304.8 m.) of single-phase line in microfarads, and a is obtained from Fig. 2 of Prof. Ryan's article. The constant k is a factor selected by judgment guided by the results of practical tests and experience. See Tables I and II on pages 70 and 71 and remarks on p. 68, Vol. 30; select $k = 0.75$;

In formula (15) above:

$d = 0.33$ in.; $a = 0.069$ in.; $b = 18.1$ in.; $t = 61.6$ deg. fahr.; $D = 72$ in. and

$$C = 1.16 \frac{0.00368}{\log\left(\frac{D}{r}\right)} = 0.00161 \text{ microfarad}$$

From (15) above: $E_{crit.} = 61.6$ kv.

From (14) above: $P = 20.8$ kw.

The kilovolts in Fig. 9 corresponding to $2 \times 20.8 = 41.6$ kw. is 63.9 kv., as against the 61.6 found by Prof. Ryan's formula.

Digitized by Google

Bearing in mind the errors likely to occur particularly on the lower part of the curve, this is certainly as good an approximation as could be expected.

In order to show the influence of the constant k of Prof. Ryan's formula, the following table has been computed:

k	E form. (15) kv.	2 Xconvection loss form. (14) kw.	Corresponding line voltage from Fig. 9 kv.
0.72	59.4	38.6	63.4
0.73	60.0	39.4	63.5
0.74	60.9	40.5	63.7
0.75	61.6	41.6	63.9
0.76	62.5	42.6	64.1
0.77	63.5	43.1	64.2
0.78	64.4	45.4	64.4
0.79	65.1	46.3	64.6

It is seen from above, that the constant k does not largely alter the result and any value between $k = 0.72$ and say $k = 0.82$ will give very good results.

The following test was started at 7.30 p.m. during heavy rain at La Fundicion; light rain, off and on, at Oroya. Probably only local showers along the line. Temperature outside Oroya power house 14.5 deg. cent. at 8.17 p.m.; barometer at Oroya 48.3 cm. and at La Fundicion 42.85, both at 7.30 p.m.

Generator voltage kv.	Line kv.*	Generator current Fig. 8 amperes	Generator† current amperes	Corrected ind. watt-meter readings kw.	Curve *A* Fig. 9 kw.	Frequency
58.6	59.4	10.1	10	60	65	60.8
61.9	62.7	8.95	9.1	83.5	86	
64.6	65.3	8.00	8.04	110.7	110.5	
66.9	67.7	7.30	6.96	138	140	
62.1	62.9	9.10	9.35	84.5	81	61.0
65.0	65.8	7.8	8.04	118	115.1	
67.2	68.0	6.5	6.78	148	143.5	
69.5	70.2	5.0	5.4	193	184	
71.5	72.2	3.6	4.22	237	234	
73.2	73.9	2.8	3.58	285		

*By interpolation from other test.
†A smaller scale ammeter used than in the first test.

Digitized by Google

At 71.8 kv. at Oroya a slight brush discharge was visible at the end of the lightning arrester horns connected to the line; the same was the case at the smelter substation. No visible corona was on the line either at Oroya or at the smelter. The night was quite dark with a new moon behind heavy clouds.

ACKNOWLEDGMENTS

In conclusion I wish to express my appreciation to Mr. F. G. Baum, Mr. J. P. Jollyman and Professor Harris J. Ryan for suggestions in the preparation of this article.

Digitized by Google

To be presented at the 335th meeting of the American Institute of Electrical Engineers, New York, December 14, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

PHENOMENA ACCOMPANYING TRANSMISSION WITH SOME TYPES OF STAR TRANSFORMER CONNECTIONS—II*

BY LLOYD N. ROBINSON

ABSTRACT OF PAPER

1. Hysteresis, as well as variation of permeability, gives rise to harmonics of considerable magnitude in the exciting current of a transformer; the components from the two sources are in quadrature for each harmonic.

2. There is a fallacy in the idea that the harmonics in the exciting current of a transformer are entirely wattless.

3. For transmission lines of modern lengths, the effect of the line is to reduce the third harmonic voltage between neutral and line terminals of a star-star connected bank of transformers having grounded neutral on the line side only.

4. In transmission with star-star transformer banks having grounded neutral on the line side only, the inter-relation of line susceptance from conductor to ground in series with the varying susceptance of the individual transformers may cause the total m.m.f. of one of the transformers to pass through zero at the same instant as the impressed e.m.f.; and thus, give opportunity for a reversal of this transformer due to inertia, thereby producing a periodically reversing leg and abnormal voltages.

5. In a similar system with high quality line insulation, the effect of atmospheric charges on the line conductors may be to cause the transformer of the bank to assume relations with one leg permanently reversed when energized from the station side; thus, imposing unbalanced voltage conditions on the bank and producing, in two of the units, fundamental frequency components of voltage 264 per cent of normal.

6. Combinations and accentuations of the above causes may, through natural requirements, give rise to a double frequency pulsation of the potential of the hypothetical neutral of the line conductors: thus, producing, in the leg voltages, second harmonic components of extremely large dimensions which are limitless so far as is yet known.

7. The above applies also in case a group of star-connected ironclad reactors, such as auto-transformers without tertiary windings, are employed to ground the neutral of an otherwise isolated neutral transmission.

8. Results, obtained in the laboratory with a three-phase star-star connected bank of transformers feeding condensers between line conductors and line side neutral, though not yet sufficiently extensive to confirm all of the above statements, show that the voltages from line terminals to neutral are in considerable measure independent of the primary impressed delta voltages so far as concerns wave shape and frequency.

Manuscript of this paper was received May 23, 1917.

*For Part I see TRANS. A. I. E. E., Vol. XXXIV, 1915, p. 2183.

Digitized by Google

Introduction

AS A general rule, the use of single-phase transformers connected star-star into a three-phase bank is considered poor electrical engineering practise. There are cases where the connection has been employed with apparently satisfactory results, but they comprise the exceptions rather than the rule. It is doubtful if many of these exceptions would be permitted if a thorough investigation were made of the stability and local voltages involved in the connection, but it is beyond the scope of this thesis to make such an investigation of all the possible cases. It is sufficient to say that where these exceptional connections, star-star, have been employed in transmission practise, special precautions have generally been taken to insure the stability of the system. Where such precautions have not been observed, disastrous results have frequently followed. The precautions have provided a remedy or even a preventive, we might say; but, because of the suddenness and sureness of the undesirable phenomena when such have occurred, it has usually been impossible to observe the actual underlying causes. Theories have attributed the effects to the third harmonic which arises when an ironclad electromagnetic circuit is energized.

Early in the year nineteen hundred and fifteen, the writer was concerned with some tests of star-star connected transformers supplying a three-phase transmission line, that developed unstable conditions and peculiar phenomena which ordinarily would not be discovered in commercial operation or without the use of an oscillograph. It is fairly safe to say that, even in these tests, the insulation of the transformers would have broken down and the windings have been burnt out before the phenomena were discovered had it not been that the impressed voltage applied to the transformers was only approximately one-quarter of the rated voltage.

First, it will be well to show why, in general, the third harmonic of magnetization can not be expected to develop sufficiently high voltages to break down the insulation of a star-star connected bank of transformers connected to a three-phase transmission line provided the windings, leads and bushings are insulated for full rated voltage of the windings, and have been subjected to tests of at least double voltage to case, core and ground and between turns.

Later, the co-ordination of these previously unrecognized phenomena with the general laws of electricity and magnetism will be submitted so far as it has been completed at this time.

Digitized by Google

Harmonics of Transformer Magnetization

So much has been said and written concerning the harmonics of magnetization of transformers, that it is hardly essential to mention it more than very briefly here. The indexes of the Transactions of the American Institute of Electrical Engineers provide ample bibliography on the subject.

From the general formula of electromagnetic induction, the induced voltage is $$e_2' = k \frac{d\phi}{dt}$$

where ϕ is the magnetic flux, t the time, and k is a constant dependent upon the number of turns in the winding, etc.

If $$\phi = \cos(a t + \alpha)$$

$$\frac{d\phi}{dt} = -a \sin(a t + \alpha)$$

whence $$e_2' = -a k \sin(a t + \alpha)$$

That is, we say a cosine wave of flux generates a sine wave of voltage, and because of the inter-relations of the sine and cosine functions, we may say that a sine wave of flux produces a cosine wave of voltage.

With a sine wave of voltage applied at the two terminals of an electric circuit, the wave of counter e.m.f. will ordinarily be a sine wave of equal magnitude but opposite sign when conditions are stable; that is, after the initial transients have disappeared.

Considering only the post-transient conditions; if a voltage, $e = c \sin a t$, is impressed on the terminals of an inductive circuit containing resistance (or equivalent resistance), the counter e.m.f. will be

$$e' = -c \sin a t$$

But e' will have two components; one, the resistance component,

$$e_1' = -b \sin(a t + \beta)$$

and the other, the reactive component,

$$e_2' = -a k \sin(a t + \alpha)$$

The current will adjust itself so that

$$c \sin a t = b \sin(a t + \beta) + a k \sin(a t + \alpha)$$

Digitized by Google

In the circuit having constant inductance, the current will be a sine wave not in phase with the impressed voltage or the counter e.m.f. The phase relation between the current and the impressed voltage depends upon the relative magnitudes of the inductive reactance, $x = 2\pi f L$, and the resistance r. The phase angle is

$$\theta = \tan^{-1}\left(\frac{x}{r}\right)$$

The number of interlinkages of an electric circuit with the lines of magnetic force of the flux produced by unit current in the circuit is called the inductance of the circuit. That is, the inductance is

$$L = m\,\frac{\phi}{i}$$

where m is a constant, ϕ is the number of lines of flux, and i is the current.

In an ironclad inductive circuit, the ratio $\frac{\phi}{i}$ is not constant, but decreases as the flux density in the iron increases. However, in order to produce a sine wave of counter e.m.f., there must be a cosine wave of flux because

$$D_x(\sin x) = \cos x, \text{ and } D_x(\cos x) = -\sin x$$

Consider, for the present, an iron magnetic circuit without hysteresis*, in order to study alone the effects of what is called the varying permeability by means of the B-H curve. B is the product of the flux multiplied by a constant, and H is the pro-

*Because of the prevalence of a sort of mystery surrounding this word, and the lack of uniformity in its use; the definition from Webster's New International Dictionary is that used and is submitted:

"Hysteresis: (a) A lagging or retardation of the effect, when the forces acting upon a body are changed, as if from viscosity or internal friction. (b) In a magnetic material, as iron, a lagging in the values of result ng magnetization (denoted by B) due to a changing magnetizing force (denoted by H). A repeated reversal of H causes a changing magnetization B as shown by the hysteresis loop or cycle...."

The meaning of the word bears a marked similarity to that of hesitate; but a search of the derivations shows that hysteresis comes from Sanskrit through the Greek, while hesitate comes through the Latin from an entirely different root.

Digitized by Google

duct of the current multiplied by a constant. Since the constants are given for any machine, by change of scale, the *B-H* curve may be translated to a $\phi - i$ curve, and this will be done in the following discussion. In Fig. 1, there is given a typical *B-H* curve for transformer iron. This *B-H* curve translated is the axis of the hysterises loop shown in Fig. 2.

For a sine wave of flux, say

$$\phi = 10 \sin a\, t$$

curve I of Fig. 3, a wave of wattless magnetizing current, i_m, like curve II of Fig. 3 will be required, based upon the i_m curve of Fig. 2.

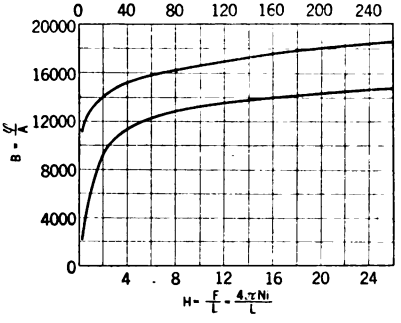


FIG. 1—AVERAGE INDUCTION CURVE—TRANSFORMER SHEETS
Standard Handbook, 1915 Edition, Sect. 4, Fig. 24

Concerned in the magnetization of the iron, there are, besides the wattless magnetizing current, the components of current due to hysteresis and to eddy currents. By the equations for eddy currents, it is possible to eliminate them from the discussion; and now consider combined the wattless component of magnetizing current and the energy component required by hysteresis. The combination is obtained from the hysteresis loop for a given wave of flux, say

$$\phi = 10 \sin at$$

The current corresponding to this flux is obtained from the i_{mh} curve of Fig. 2 and plotted as curve III of Fig. 3.

The co-ordinates of the curves of Fig. 3 are given in Table I, By harmonic analysis, the coefficients of the Fourier series for these three waves are determined and tabulated in Table II.

Digitized by Google

In the circuit having constant inductance, the current will be a sine wave not in phase with the impressed voltage or the counter e.m.f. The phase relation between the current and the impressed voltage depends upon the relative magnitudes of the inductive reactance, $x = 2\pi f L$, and the resistance r. The phase angle is

$$\theta = \tan^{-1}\left(\frac{x}{r}\right)$$

The number of interlinkages of an electric circuit with the lines of magnetic force of the flux produced by unit current in the circuit is called the inductance of the circuit. That is, the inductance is

$$L = m\,\frac{\phi}{i}$$

where m is a constant, ϕ is the number of lines of flux, and i is the current.

In an ironclad inductive circuit, the ratio $\frac{\phi}{i}$ is not constant, but decreases as the flux density in the iron increases. However, in order to produce a sine wave of counter e.m.f., there must be a cosine wave of flux because

$$D_x(\sin x) = \cos x, \text{ and } D_x(\cos x) = -\sin x$$

Consider, for the present, an iron magnetic circuit without hysteresis*, in order to study alone the effects of what is called the varying permeability by means of the B-H curve. B is the product of the flux multiplied by a constant, and H is the pro-

*Because of the prevalence of a sort of mystery surrounding this word, and the lack of uniformity in its use; the definition from Webster's New International Dictionary is that used and is submitted:

"Hysteresis: (a) A lagging or retardation of the effect, when the forces acting upon a body are changed, as if from viscosity or internal friction. (b) In a magnetic material, as iron, a lagging in the values of result ng magnetization (denoted by B) due to a changing magnetizing force (denoted by H). A repeated reversal of H causes a changing magnetization B as shown by the hysteresis loop or cycle...."

The meaning of the word bears a marked similarity to that of hesitate; but a search of the derivations shows that hysteresis comes from Sanskrit through the Greek, while hesitate comes through the Latin from an entirely different root.

Digitized by Google

duct of the current multiplied by a constant. Since the constants are given for any machine, by change of scale, the *B-H* curve may be translated to a $\phi - i$ curve, and this will be done in the following discussion. In Fig. 1, there is given a typical *B-H* curve for transformer iron. This *B-H* curve translated is the axis of the hysterises loop shown in Fig. 2.

For a sine wave of flux, say

$$\phi = 10 \sin a\, t$$

curve I of Fig. 3, a wave of wattless magnetizing current, i_m, like curve II of Fig. 3 will be required, based upon the i_m curve of Fig. 2.

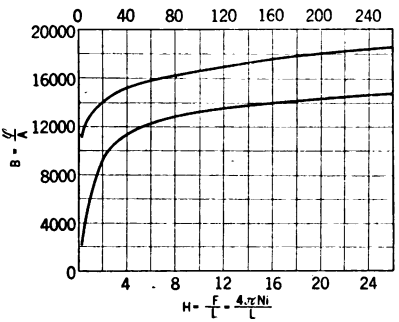


FIG. 1—AVERAGE INDUCTION CURVE—TRANSFORMER SHEETS
Standard Handbook, 1915 Edition, Sect. 4, Fig. 24

Concerned in the magnetization of the iron, there are, besides the wattless magnetizing current, the components of current due to hysteresis and to eddy currents. By the equations for eddy currents, it is possible to eliminate them from the discussion; and now consider combined the wattless component of magnetizing current and the energy component required by hysteresis. The combination is obtained from the hysteresis loop for a given wave of flux, say

$$\phi = 10 \sin at$$

The current corresponding to this flux is obtained from the i_{mh} curve of Fig. 2 and plotted as curve III of Fig. 3.

The co-ordinates of the curves of Fig. 3 are given in Table I, By harmonic analysis, the coefficients of the Fourier series for these three waves are determined and tabulated in Table II.

Digitized by Google

In the circuit having constant inductance, the current will be a sine wave not in phase with the impressed voltage or the counter e.m.f. The phase relation between the current and the impressed voltage depends upon the relative magnitudes of the inductive reactance, $x = 2\pi f L$, and the resistance r. The phase angle is

$$\theta = \tan^{-1}\left(\frac{x}{r}\right)$$

The number of interlinkages of an electric circuit with the lines of magnetic force of the flux produced by unit current in the circuit is called the inductance of the circuit. That is, the inductance is

$$L = m\,\frac{\phi}{i}$$

where m is a constant, ϕ is the number of lines of flux, and i is the current.

In an ironclad inductive circuit, the ratio $\frac{\phi}{i}$ is not constant, but decreases as the flux density in the iron increases. However, in order to produce a sine wave of counter e.m.f., there must be a cosine wave of flux because

$$D_x(\sin x) = \cos x, \text{ and } D_x(\cos x) = -\sin x$$

Consider, for the present, an iron magnetic circuit without hysteresis*, in order to study alone the effects of what is called the varying permeability by means of the B-H curve. B is the product of the flux multiplied by a constant, and H is the pro-

*Because of the prevalence of a sort of mystery surrounding this word, and the lack of uniformity in its use; the definition from Webster's New International Dictionary is that used and is submitted:

"Hysteresis: (a) A lagging or retardation of the effect, when the forces acting upon a body are changed, as if from viscosity or internal friction. (b) In a magnetic material, as iron, a lagging in the values of result ng magnetization (denoted by B) due to a changing magnetizing force (denoted by H). A repeated reversal of H causes a changing magnetization B as shown by the hysteresis loop or cycle...."

The meaning of the word bears a marked similarity to that of hesitate; but a search of the derivations shows that hysteresis comes from Sanskrit through the Greek, while hesitate comes through the Latin from an entirely different root.

Digitized by Google

duct of the current multiplied by a constant. Since the constants are given for any machine, by change of scale, the *B-H* curve may be translated to a $\phi - i$ curve, and this will be done in the following discussion. In Fig. 1, there is given a typical *B-H* curve for transformer iron. This *B-H* curve translated is the axis of the hysterises loop shown in Fig. 2.

For a sine wave of flux, say

$$\phi = 10 \sin a\, t$$

curve I of Fig. 3, a wave of wattless magnetizing current, i_m, like curve II of Fig. 3 will be required, based upon the i_m curve of Fig. 2.

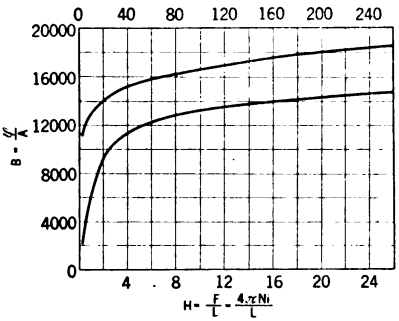


FIG. 1—AVERAGE INDUCTION CURVE—TRANSFORMER SHEETS
Standard Handbook, 1915 Edition, Sect. 4, Fig. 24

Concerned in the magnetization of the iron, there are, besides the wattless magnetizing current, the components of current due to hysteresis and to eddy currents. By the equations for eddy currents, it is possible to eliminate them from the discussion; and now consider combined the wattless component of magnetizing current and the energy component required by hysteresis. The combination is obtained from the hysteresis loop for a given wave of flux, say

$$\phi = 10 \sin at$$

The current corresponding to this flux is obtained from the i_{mh} curve of Fig. 2 and plotted as curve III of Fig. 3.

The co-ordinates of the curves of Fig. 3 are given in Table I, By harmonic analysis, the coefficients of the Fourier series for these three waves are determined and tabulated in Table II.

Digitized by Google

It is noted that the sine coefficients of the curve III are practically equal to the sine coefficients of curve II. The discrepancies are due to the facts that only eighteen ordinates per half wave were used in the analysis, and that the computations were carried to only three decimal places at most. This agreement between the sine coefficients of II and III is due to the fact that the i_m curve of Fig. 2 is the axis of the i_{mh} curve, so that

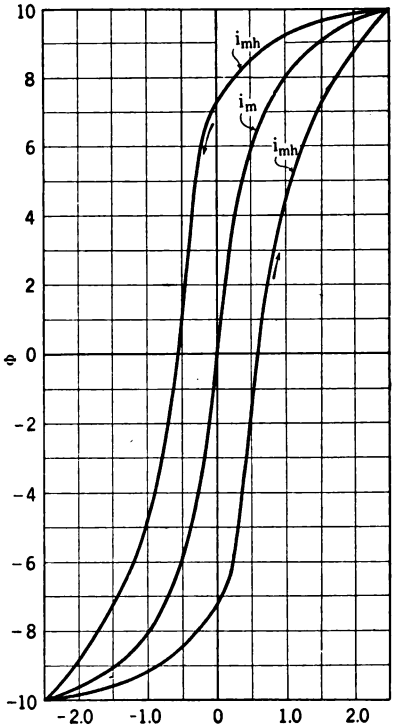


FIG. 2—AVERAGE HYSTERESIS LOOP
Standard Handbook, 1915 Ed., Sect. 4, Fig. 25

the components of current in phase with the flux in the two cases are identical.

It is interesting to note further in curve III that the cosine coefficients are practically one-half the sine coefficients for the fundamental and triple harmonics. In the early discussion of the third harmonic due to transformer magnetization, the harmonics were attributed entirely to hysteresis. Later this was shown to be erroneous and it was fairly generally accepted that the harmonics were almost entirely due to the variation of per-

Digitized by Google

meability. One of the favorite arguments supporting the latter is, there is no triple harmonic voltage impressed on the transformer and consequently the triple harmonic component of the exciting current must be entirely wattless. From the coefficients in Table II, it is seen that in this average iron at not abnormal maximum density, hysteresis introduces triple harmonic components of exciting current in quadrature with those introduced by the variation of permeability, and of practically half the magnitude of the latter. Therefore it can not be said that the triple harmonic components in the exciting current of a transformer are due to the hysteresis alone or to the variation of per-

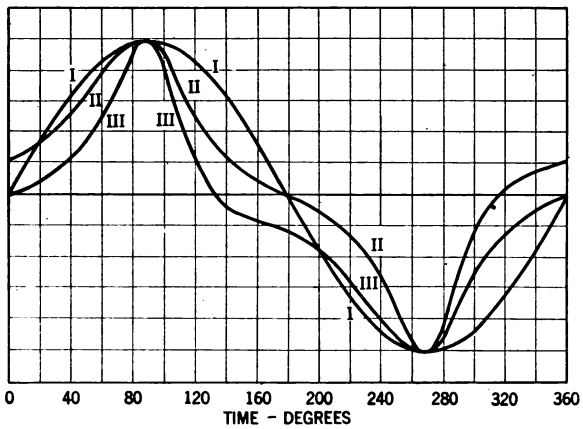


FIG. 3

I—MAGNETIC FLUX
II—WATTLESS MAGNETIZING CURRENT
III—CURRENT REQUIRED BY THE HYSTERESIS LOOP

meability alone. They are produced by the combination of the two.

The components of exciting currents attributed to eddy currents are generally found to contain some small harmonics, but these are present due to the fact that the wave of flux, ultimately produced, is not a pure sine wave, and consequently eddy currents of harmonic frequency are present in the core.

If there is presented a closed circuit for the harmonic components of the exciting current, they will flow in order to adjust the current to the counter e.m.f. requirements. Obviously, these harmonic currents flowing, for example, through the resistance of a generator winding or closed delta of a transformer bank give

Digitized by Google

rise to energy losses. That is, they are not wattless. What really takes place is a conversion of frequency within the transformer.

TABLE I

CO-ORDINATES OF CURVES I, II, III, FIG. 3

Abscissas at deg.	sin at	I $\phi = 10 \sin at$	II current i_m	III current i_{mh}
0	0	0	0	0.57
10	0.174	1.74	0.11	0.70
20	0.342	3.42	0.23	0.84
30	0.500	5.00	0.40	1.07
40	0.643	6.43	0.60	1.35
50	0.766	7.66	0.90	1.63
60	0.866	8.66	1.30	1.96
70	0.940	9.40	1.78	2.25
80	0.985	9.85	2.30	2.44
90	1.000	10.00	2.50	2.50
100	0.985	9.85	2.30	2.10
110	0.940	9.40	1.78	1.26
120	0.866	8.66	1.30	0.63
130	0.766	7.66	0.90	0.17
140	0.643	6.43	0.60	−0.17
150	0.500	5.00	0.40	−0.29
160	0.342	3.42	0.23	−0.38
170	0.174	1.74	0.11	−0.47
180	0	0	0	−0.57
190	−0.174	−1.74	−0.11	−0.70
200	−0.342	−3.42	−0.23	−0.84
etc.	etc.	etc.	etc.	etc.

TABLE II

FOURIER COEFFICIENTS FOR CURVES I, II, III, FIG. 3

Order of Harmonic	I Flux		II i_m		III i_{mh}	
	sine coeff.	cosine coeff.	sine coeff.	cosine coeff.	sine coeff.	cosine coeff.
1	10	0	1.708	0	1.693	0.801
3	0	0	−0.557	0	−0.552	−0.243
5	0	0	0.158	0	0.167	−0.011
7	0	0	−0.053	0	−0.051	0.029
9	0	0	0.018	0	0.027	−0.013
11	0	0	−0.009	0	−0.013	0.025
13	0	0	0.001	0	0.004	−0.022
15	0	0	0.008	0	0.006	0.003

Digitized by Google

Because the impressed voltage contains no harmonic components is no more ground for saying that the triple harmonic components of transformer exciting current are entirely wattless than it is for concluding that the sixty-cycle currents on the secondary side of a 25- to 60-cycle frequency changer set must be entirely wattless. In the latter case, we have energy transformation from electrical to magnetic to mechanical to magnetic to electrical; while in the former there is a more direct transformation from electrical to magnetic to electrical.

TRIPLE HARMONICS IN THREE-PHASE BANKS OF TRANSFORMERS.

In a bank of three identical transformers connected star on the primary side and operating under normal balanced conditions on a three-phase system, the voltages between the terminals of the individual transformers, that is, the voltages between the

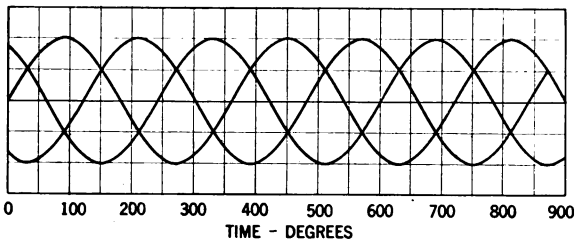


FIG. 4—VOLTAGE RELATIONS—LINES TO NEUTRAL—THREE-PHASE STAR-CONNECTED TRANSFORMER BANK—BALANCED NORMAL CONDITIONS.

line terminals and neutral, are alike in wave shape, equal in magnitude and displaced from each other by one-third cycle, or 120 time-degrees. Three such voltages are shown in Fig. 4, sine waves of impressed voltage being assumed for simplicity.

It has been shown above that ordinarily, when a transformer is energized, there are produced currents of harmonic frequency in the effort to adjust the counter e.m.f. to the impressed. If three identical transformers have impressed upon them e.m.fs., which are identical in wave shape and magnitude, the exciting currents will be identical in wave shape and magnitude. If the three e.m.fs. impressed upon the three identical transformers, are displaced from each other by 120 time-degrees, the corresponding exciting current waves will be displaced from each other by 120 time-degrees.

Since the three exciting current waves are equal in shape and

Digitized by Google

magnitude and are 120 time-degrees apart, the fundamental components of the exciting currents will be equal in shape and magnitude and 120 time-degrees apart. Since the three exciting current waves are identical in shape and magnitude, harmonics of equal order and magnitude exist in each, and these harmonics bear identical phase relations to their respective fundamental components. That is, if the n th harmonic in the exciting current of transformer No. 1 is $k_n \sin (n\theta + \alpha_n)$, the n th harmonic in the exciting current of transformer No. 2 is $k_n \sin (n (\theta \pm 120°) + \alpha_n)$, and that in transformer No. 3 is $k_n \sin (n (\theta \pm 240°) + \alpha_n)$. The values of the variable parts of these expressions are given in Table III for odd values of n.

TABLE III

n	$\sin (n\theta + \alpha_n)$	$\sin (n (\theta + 120°) + \alpha_n)$	$\sin (n (\theta + 240°) + \alpha_n)$
1	$\sin (\theta + \alpha_1)$	$\sin (\theta + \alpha_1 + 120°)$	$\sin (\theta + \alpha_1 + 240°)$
3	$\sin (3\theta + \alpha_3)$	$\sin (3\theta + \alpha_3)$	$\sin (3\theta + \alpha_3)$
5	$\sin (5\theta + \alpha_5)$	$\sin (5\theta + \alpha_5 + 240°)$	$\sin (5\theta + \alpha_5 + 120°)$
7	$\sin (7\theta + \alpha_7)$	$\sin (7\theta + \alpha_7 + 120°)$	$\sin (7\theta + \alpha_7 + 240°)$
9	$\sin (9\theta + \alpha_9)$	$\sin (9\theta + \alpha_9)$	$\sin (9\theta + \alpha_9)$
11	$\sin (11\theta + \alpha_{11})$	$\sin (11\theta + \alpha_{11} + 240°)$	$\sin (11\theta + \alpha_{11} + 120°)$
13	$\sin (13\theta + \alpha_{13})$	$\sin (13\theta + \alpha_{13} + 120°)$	$\sin (13\theta + \alpha_{13} + 240°)$
15	$\sin (15\theta + \alpha_{15})$	$\sin (15\theta + \alpha_{15})$	$\sin (15\theta + \alpha_{15})$
17	$\sin (17\theta + \alpha_{17})$	$\sin (17\theta + \alpha_{17} + 240°)$	$\sin (17\theta + \alpha_{17} + 120°)$

From Table III and the foregoing, it is seen that the components of third, ninth, fifteenth and of other triple harmonic frequencies in the three exciting currents are respectively identical in phase position as well as in magnitude; that is, the triple harmonics of the same order in the three transformers are displaced from each other by zero time-degrees; while the components of fifth, seventh, eleventh and of other non-triple harmonic frequencies have mutual three-phase displacements of 120 time-degrees.

In general, the magnitudes of the harmonic components in the exciting current of a transformer vary inversely with the orders of the harmonics though not necessarily in inverse proportion. Thus, it is seen that the third harmonic is usually the largest component except the fundamental. For this reason, and because of the above mentioned lack of phase displacement between the triple harmonics in the exciting currents of a three-phase bank of transformers connected star on the primary side; the third harmonic deserves, and has received, the most con-

Digitized by Google

sideration of any of the harmonics produced in the energization of transformers.

Star-Delta. In a three-phase bank of transformers with primary connected star, and secondary connected delta, as in Fig. 5; the triple harmonic components of exciting current, being in phase in all three transformers, tend to flow, say, from line

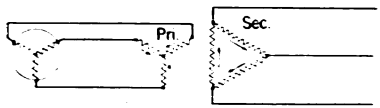


FIG. 5

terminals to neutral at a given instant. The primary neutral is insulated so that these triple harmonic currents can not flow in the primary winding. The lack of these triple harmonics of exciting current distorts the waves of flux in the cores so that the latter contain triple harmonics. Then the voltages, induced in the primary and secondary windings by the variations of the flux, contain triple harmonics, which are in phase in all three of the transformers. These triple harmonic voltages, being in phase with each other, tend to establish currents in the same direction in all three transformers, and these triple harmonic currents actually obtain in the transformer operation, flowing around the closed delta secondary as indicated by the solid arrows in Fig. 5. These triple harmonic currents in the secondary windings establish corresponding triple harmonic fluxes which neutralize the distortion of the flux waves originally caused by

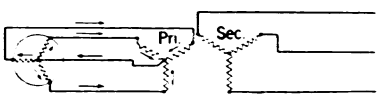


FIG. 6

the absence of triple harmonic components in the primary exciting current. In effect, the result is, insofar as concerns the transformation of voltage, practically the same as if the triple harmonic currents were present in the primary exciting current. In fact, under such conditions, we say that the triple harmonics of exciting current flow in the secondary delta.

Star-Star with Four-Wire Primary. In a three-phase bank of transformers connected star-star with the primary neutral

Digitized by Google

connected to the generator neutral, as in Fig. 6; the triple harmonic components of exciting currents are established in the primaries of the transformers with the neutral as a common wire thence in the generator windings and return through the phase wires, as indicated by the arrows in the diagram, Fig. 6.

Star-Star with Isolated Neutrals. In the star-star connected bank of Fig. 7, both the primary and secondary neutrals are insulated, so that no third harmonic components of the exciting current can exist. In such a case the flux waves are badly distorted, and consequently the voltages between lines and neutral contain large triple harmonic components. Since, in a bank of three identical transformers in normal balanced conditions, the respective triple harmonics are equal and in phase in all three transformers, the differences of the triple harmonic components in any two transformers are zero, so that the triple harmonic voltages will not appear between line terminals.

Under average operating flux densities, the third harmonic component in the voltage from line to neutral, in a bank of trans-

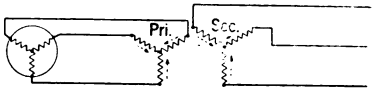


FIG. 7

formers connected as in Fig. 7, may be 60 per cent of the rated fundamental component *. It is obvious that this will cause a serious extra strain on the insulation if the phase relation between the fundamental and the third harmonic components of voltage in a transformer is such as to result in increasing the maximum value of the total voltage wave by 60 per cent.

If, in Fig. 7, the generator neutral is grounded, the triple harmonic components of voltage will be manifested between primary neutral and ground. Also, if the line, to which the secondary is connected, feeds a grounded neutral load, or if the secondary line is so extensive that the admittance between the lines and ground is very large compared to the admittance between the secondary neutral and ground, the triple harmonic voltages will appear between secondary neutral and ground.

Other Types of Connections. The possible three-phase connections and combinations of the above simple cases are innumerable

*Louis F. Blume, TRANS. A. I. E. E, 1914 p. 751.

Digitized by Google

because they include banks made up of dissimilar transformers. But the triple harmonic phenomena concerned in such connections are fundamentally and essentially the same in all.

One more possible connection will be discussed because it gives rise to rather unique conditions and because upon it the main part of the thesis will dwell.

Star-Star with Grounded Neutral on Line Side Only. In the case of a bank of three identical transformers supplied from an isolated neutral three-phase source, the bank connected star-star with grounded neutral on the line side only and feeding an extensive transmission line, as shown in Fig. 8, there is no path for triple harmonics of exciting current in the primaries, but the admittances between the line conductors and ground complete the circuits so that the triple harmonic exciting currents can be established in the secondary windings through the neutral as a common wire, thence through the admittances between neutral

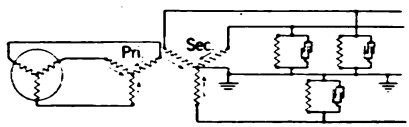


FIG. 8

and line conductors and return via the latter as indicated by the heavy arrows in the diagram, Fig. 8.

Since the primary is essentially open-circuited for currents, that are in phase in all three transformers, it is seen that these triple harmonic secondary currents are truly exciting currents, and as such are affected by the exciting reactance (exciting susceptance divided by the square of the exciting admittance) of the transformers.

In the case of modern transmission lines and networks, often involving 100 miles, and sometimes many hundreds of miles of line it is easily seen that the impedance offered by the line admittance to ground may be very small compared to the open-circuit impedance of a transformer even for currents of fundamental frequency. The reactance of the transformer is inductive and will be much larger at third harmonic frequency than at fundamental. On the other hand, the equivalent reactance of the line is capacitive, and is consequently much less at third harmonic frequency than at fundamental. So that, for the third harmonic exciting currents, the impedances offered between line conduc-

Digitized by Google

tors and ground may be negligible compared to the internal impedances of the transformers. This means that the major part of the third harmonic voltages, which maintains the third harmonic secondary current, is consumed in the transformer winding and that only a very small portion of this third harmonic voltage appears across the terminals of the transformer between line conductor and ground. Essentially, the arrangement is similar to a generator of very high internal impedance, generating a voltage of third harmonic frequency which is applied to a load of comparatively low impedance. It is so like the phenomena of some types of constant current generators that the third harmonic of exciting current is often said to have constant current regulation

From the above considerations, it is seen that, in cases of long transmission lines connected to star-star transformer banks, having grounded neutral on the line side only, the voltage from line terminal to neutral is not necessarily materially augmented by a third harmonic.

Hence, the theory, that the breakdowns of insulation and burn-outs, which have accrued with this type connection, were due to the third harmonic voltage between line terminals and ground, at least loses weight as a general explanation.* Also the anxiety over triple harmonic electrostatic induction in communication circuits strung in the neighborhood of such power lines is allayed.†

Even Harmonic Phenomena

As mentioned before, about two years ago some tests of a star-star connected transformer bank supplying a three-phase transmission line, developed unstable conditions and peculiar phenomena, which had not been observed in any previous tests or operation of such banks so far as general opinion and a survey of the literature on transformers disclosed. The entire absence of any direct-current component in the transformer currents, and the stable operation of the transformers at impressed voltages slightly less than those that gave rise to the phenomena, eliminated the possibility that residual magnetism or direct-current excitation, as ordinarily understood, were responsible for the phenomena.‡ Because of the apparent novelty of the

*L. N. Robinson, A. I. E E. Trans. 1915, Vol. XXXIV, Part II, p. 2183-2184 and 2189-2191.

†H. S. Osborne, A. I. E. E. Trans. 1915, Vol. XXXIV, Part II, p. 2175-2179.

‡J. B. Taylor, Trans, A. I. E. E., 1909, pp. 725–732.

Digitized by Google

phenomena, the writer became interested in establishing an explanation consistent with the generally accepted fundamental laws of electricity and magnetism.

The phenomena were accompanied by vibrations and noises issuing from the transformers, and therefore it was first supposed that the trouble might be due to a loose coil or loose iron vibrating in response to the repulsion or attraction of the alternating magnetic fields. The transformers were new from the factory and had never before been in service, so they were tested. The low-tension windings were short-circuited and five times normal current was alternately suddenly applied to, and suddenly removed from, the high-tension windings several times. All the three transformers in the bank were tested thus, and none of them emitted any noise or showed any other signs of distress.

There was available another bank of transformers that had previously been in commercial service several months, and in testing service a year and a half. The transformers of this bank differed from the first in practically every essential even to the name of the manufacturer. This is shown by the following tabular comparison of their ratings:

	Bank No. 1	Bank No. 2
Manufacturer.....	*A*	*B*
Type.....	Core	Core
Frequency (cycles)....	50	60
Kilovolt-amperes per unit.....	37.5	50
High-tension volts....	15000/14250/12980	22000/21450/20900/20350
	12540/7500/7125	19800/11000/10800/9960
Low-tension volts.....	440/220/110	2400/480

The tests on the first bank had given rise to a new theory in explanation of the phenomena. In several instances, by this theory, it was possible, by estimates based upon quite crude data, to predict, within a few per cent, at what impressed voltage the phenomena would occur in the second bank. In one case in particular, certain phenomena were predicted at a certain impressed voltage and the prediction was fulfilled although, when tried, they did not obtain at an impressed voltage thirteen per cent lower.

While these numerous fulfilled predictions added much weight to, and tended to sustain, the theory, they did not necessarily clearly and conclusively establish it. The explanation of the phenomena, so far as they had been analyzed, was submitted

Digitized by Google

to the American Institute of Electrical Engineers at the September meeting of 1915.* Since the ensuing discussion did not develop a sufficiently definite contradiction of the theory, there was impetus added to further investigation.

Briefly, the original observations involved several different conditions:

"1. A star-star bank, with generator neutral isolated and line-side neutral grounded. The duty was charging a line 37 miles long.

"2. Another bank similarly connected, but composed of units made by a different manufacturer and of different ratings in every respect. The duty of this bank was the same as for that in case 1 but on another day.

"3. A bank of 1 to 1 auto-transformers connected star with grounded neutral, at the sending end of the 37-mile line, which was charged by a delta-delta bank."

"4. A bank of transformers stepping down from isolated neutral star to 'interconnected delta'. In this instance, the current circulating in the 'interconnected delta' contained prominent even harmonics.

"5. A bank of 13,200 to 110-volt potential transformers connected star with grounded neutral to the sending end of the 37-mile line, which was supplied from a delta-star bank with isolated neutral. The secondaries of the potential transformers were open-circuited."

I. "In some cases, when charging the line from transformers connected star-star with grounded neutral on the line side, an undertone of one-half fundamental frequency was present in the leg voltages (voltages from line terminal to neutral) and in the currents on the generator side of the bank."

II. "In some other cases, two of the leg voltages were approximately $\sqrt{7/3}$ times the delta voltage (voltage between line terminals), while the magnitude of the voltage of the third leg was approximately normal; that is, 58 per cent of the delta voltage. The leg voltages had distinctly different wave shapes, and their fundamental components were conspicuously not 120 time degrees apart in phase." "The currents in the buses on the generator side of the bank were several times normal."

III. "In still other cases, the leg voltages had double frequency components, approximately four times as large as the

*L. N. Robinson, TRANS, A. I. E. E., 1915, pp. 2183–2195.

Digitized by Google

fundamental components, and the transformers vibrated internally."

IV. "In the case of the 1 to 1 auto-transformers, the delta voltages were affected by the phenomena, becoming nearly twice as great as existed when the auto-transformers were not connected to the line. The delta voltages were of fundamental frequency with no double frequency component, while the leg voltages contained the large double frequency component."

"In all cases in which the second harmonic was prominent in the leg voltages, it was in time-phase in all three legs. This was proved by oscillograms of the simultaneous values of the three leg voltages, by a measurement of their vector sum, and by fact that the second harmonic was not in the waves of delta voltages."

Periodically Reversing Leg. In submitting the previous paper to the Institute, it was said that: "The case (I above) in which the second undertone, or 'one-half' harmonic was present, is explanable by a periodically reversing leg; *i.e*, one leg of the bank reversed once for each fundamental cycle, so that the fundamental component of current in the leg tended to flow in the same direction through the unit during the entire cycle. In the next cycle the leg reversed again, so that the fundamental component of current tended to flow in the opposite direction from that in the previous cycle."

By this it is meant that the transformers, originally in the relative electrical positions of Fig. 9, reversed at some point in the cycle and assumed the relative positions of Fig. 10; and that at a corresponding point in the next cycle they reversed back to the position of Fig. 9, etc. Because the delta voltages are fixed by the three-phase generator, the vector differences, by pairs, of the fundamental components of the three leg voltages must be equal in magnitude and their vectors must close an equilateral triangle for the conditions of both Fig. 9 and of Fig. 10. This requirement is met by the vector arrangement of the fundamental components of leg voltages shown in Figs. 11 and 12 respectively.

While this gives analytical and graphical illustration of the phenomena, it brings up the question, how can there be a periodically reversing leg in the absence of any pole changing devices?

Causes. As mentioned above, the phenomena were discovered under conditions shown in Fig. 8. In the star-connected, three-phase transformer bank, under normal, stable conditions the fundamental components of the primary impressed voltages may

Digitized by Google

be represented by vectors as in Fig. 13. $\dot{E}_A$, $\dot{E}_B$ and $\dot{E}_C$ represent the voltages impressed upon the bank between line terminals; and $\dot{E}_1$, $\dot{E}_2$ and $\dot{E}_3$ represent the voltages impressed upon the individual transformers No. 1, 2 and 3 respectively.

$$\dot{E}_A = \dot{E}_1 - \dot{E}_2, \dot{E}_B = \dot{E}_2 - \dot{E}_3 \text{ and } \dot{E}_C = \dot{E}_3 - \dot{E}_1.$$

If a line in the plane of the diagram, Fig. 13, is rotated about the origin as axis, at a constant angular velocity of $2\pi f$ radians per second, where f is the frequency of the fundamental voltages in cycles per second; the magnitudes of the different voltages will be equal to the intercepts upon this line of the circles whose vector diameters represent the maxima of the respective voltage waves. The relative instantaneous values of these six voltages are given in Fig. 15 (a to 1) for each twelfth of one cycle, as indicated.

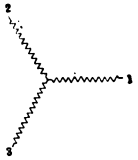


FIG. 9

FIG. 10

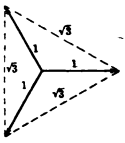


FIG. 11

The fundamental components of the secondary voltages may be represented in similar fashion differing from the respective primary impressed voltages in magnitude according to the ratio of transformation, and in phase by approximately π radians.

For present purposes, the secondaries of any two of the transformers, say Nos. 1 and 2, of the bank may be resolved into the typical circuit shown in Fig. 14. While in the actual case, the generator is not electrically connected to the secondary of the transformer, the generators shown in Fig. 14 serve merely to represent the sources of the fundamental frequency voltages, $\dot{E}_1$ and $\dot{E}_2$, and combined they are the sources of $\dot{E}_A$.

These fundamental frequency voltages give rise to fundamental frequency currents in the respective circuits of Fig. 14. These currents involve magnetomotive forces that produce magnetic fluxes in the transformer cores. Because these cores are iron, the ratio, B/H or ϕ/i, varies during each cycle, following a hysteresis loop like that of Fig. 2, Consequently, the inductance

Digitized by Google

of the circuit varies because the inductance is the ratio, ϕ/i, multiplied by a constant.

Under the discussion of "Star-Star Connection with Grounded Neutral on Line Side Only" above, it was shown that the inductive exciting reactance of the transformer might be smaller than, equal to, or greater than, the series capacitive reactance of the line. Since the manner of variation of B/H, or ϕ/i, is dependent upon the maximum value of ϕ, or of i, and since these depend in turn upon the maximum value of the voltage, E_1 or E_2; it is seen that by varying the voltage a value will be reached where the circuit becomes resonant; that is, where the inductive reactance of the transformers and line becomes equal in magnitude and opposite in sign to the capacitive reactance.

This leads directly to the most interesting fact, that the sum of the magnetomotive forces in the transformer, primary and

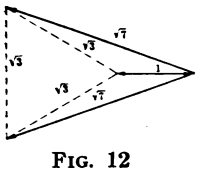


FIG. 12

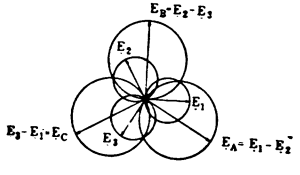


FIG. 13

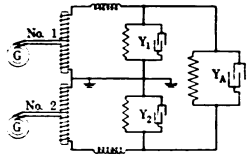


FIG. 14

secondary combined,* will pass through zero at the same instant as the impressed voltage, E_1, for some value of this voltage.

Consider now the hysteresis loop of Fig. 16. The dashed loop is the one that would obtain under normal stable, or balanced, conditions such as shown in Figs. 9 and 11. Starting from the point, A, the flux will vary along the curve to B as indicated by the arrow. If, as the total magnetomotive force passes through zero at this point, B, the voltage, E_1, also passes through zero; the electrical circuits of transformer No. 1 are collapsed; that is, E_1 is passing through the value shown in Fig. 15 (d). In the succeeding instant, as E_1 increases, the transformer No. 1 may assume the position of Fig. 9 or the reversed position of Fig. 10. Which will it select? Nature demands the easiest course, so it will select the reversed relations of Fig. 10 and 12.

At the point, B of Fig. 16, there is energy stored in the core.*

*C. P. Steinmetz, "Theory and Calculation of Electric Circuits," p. 219, Fig. 106.

*C. P. Steinmetz, "Theory and Calculation of Electric Circuits," p. 56, §36.

Digitized by Google

Where there is stored energy, there is inertia, either positive or negative. In the magnetic field or moving body, there is positive inertia; that is a tendency to resist alteration of conditions. In the electric field or breech full of gunpowder, there is negative inertia, called a charge; that is, when released, by short-circuiting the condenser or igniting the powder, the stored energy assists alteration with maximum effect at the start. In some cases, both positive and negative inertia exist, *e.g.* in electromagnetic phenomena. A most striking illustration is a carload of gunpowder standing on a track. If a source of motive

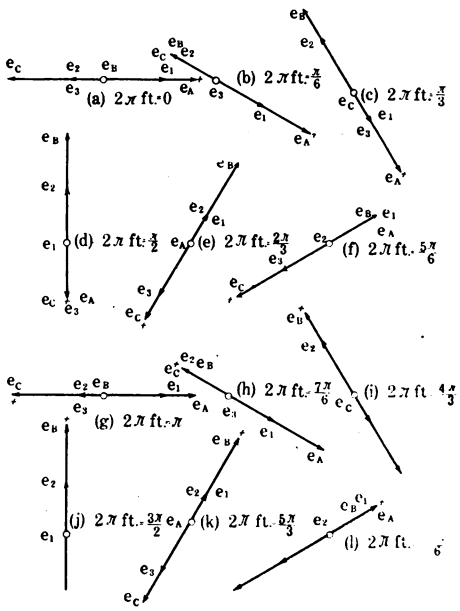


FIG. 15

power is applied, the positive inertia of the car and its load tend to keep the car at rest. If a spark touches the gunpowder, the negative inertia comes into action and an opposite result follows. This distinction of sign of inertia is borne out in consideration of electric and magnetic circuits because the inductance of an electric circuit holds a place in the fundamental equations analogous to the moment of inertia in the equations of mechanics, and the capacitance holds a place analogous to the elasticity of a spring. Of course, elasticity is not synonomous with negative inertia. It is the elastic quality, of the

Digitized by Google

material, that induces storage of energy in such manner as to create negative inertia.

From the standpoint of inertia, when the m.m.f. is altered by a small amount from that at the point, B on the loop of Fig. 16, only a slight change in ϕ will be required if the flux proceeds along the solid curve toward C; that is, little inertia need be overcome; whereas a large change in ϕ will be required to carry the flux along the dashed curve toward K.

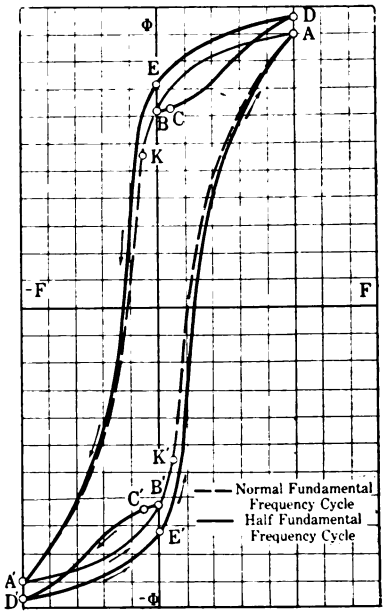


FIG. 16—HYSTERESIS LOOP FOR "REVERSING LEG"

To store more energy or to extract some of the stored energy would require an expenditure of energy proportional to the amount of energy to be stored or extracted. The expenditure of energy results in work being done. To change the amount of stored energy represented by the flux at the point, B, to that at the point, K, would demand that an amount of work be done which is proportional to the increment of m.m.f. multiplied by the difference of the fluxes; that is, the work would be approximately

$$W_K = \frac{F_K (\phi_K - \phi_B)}{2}$$

Digitized by Google

Whereas, to change the stored energy from that at B to that at C would require approximately

$$W_C = \frac{F_C\ (\phi_C - \phi_B)}{2}$$

for an increment of m.m.f. equal in magnitude to F_K.

It is seen from the diagram, Fig. 16, that $\phi_C - \phi_B$ is less than $\phi_K - \phi_B$ in magnitude,
and since

$$F_K = -F_C$$

$$W_C = \frac{F_C\ (\phi_C - \phi_B)}{2} \text{ is less than } W_K = \frac{F_K\ (\phi_K - \phi_B)}{2}$$

Hence, by both the theories of inertia and of least work, one of the transformers of the bank will reverse under the given conditions.

After the transformer flux has started from the point, B, toward the point, C, it will continue along the solid curve to a point, D, where the maximum m.m.f. is reached, because the impressed voltage is continuously applied. If F_D is equal to, or greater than, F_A, ϕ_D will be greater than ϕ_A because of the energy stored at the point, B, where $F=0$; just as a separately excited generator will build up to higher value of voltage if it has some initial magnetism than it will if the flux is initially zero.

As the m.m.f. decreases, the flux will follow the solid curve from D to E, where ϕ_E is different from ϕ_B; so that, when the curve crosses the axis at E, the magnetomotive force, F, and the impressed voltage, E_1, do not pass through zero together. Consequently another reversal does not take place at the point, E, but the flux proceeds along the solid curve to the point, A', and thence to B', where another reversal takes place, returning the transformers to the relative positions of Figs. 9 and 11; and so on, reversing once in each fundamental cycle.

If the magnetomotive force or voltage waves contain harmonic components, the problem becomes more complicated; but the phenomena of periodic reversal will obtain when the impressed voltage and circuit conditions are such that the sum of the magnetomotive forces in the transformer passes through its zero value at the same instant as the impressed voltage.

Digitized by Google

The effect of this periodic reversal is to distort the voltages between line terminals and neutral as indicated by Figs. 11 and 12, and to introduce high harmonics because of the enormous magnetic densities to which transformers No. 2 and 3 are subjected.

Since the period of a total cycle of a reversing leg is twice as long as the fundamental frequency cycle of the impressed voltage, the phenomena are easily distinguishable by the presence of a second undertone, or "one-half" harmonic, in the voltages between line terminals and neutral.

Tests. It was attempted to simulate the conditions of Fig. 8 in the laboratory by using three similar 10 kv-a. transformers. Unstable conditions were obtained, but almost as soon as they appeared, arcs would develop in the condensers, producing large, very high-frequency effects that made the recording of oscillograms useless. The only condensers, that were available and at all suitable for the purpose, were one microfarad and two microfarad paraffin paper telephone condensers which apparently are not of sufficient dielectric strength. Other methods of obtaining the conditions are under consideration and will be tried as soon as possible.

Permanently Reversed Leg. The previous paper disposed of Case II by saying: "In the case with the stable unbalanced leg voltage condition, the neutral on the generator side of the bank assumed a fixed position with one leg reversed so that the voltages from two of the line conductors to neutral were approximately $\sqrt{7}$, (2.64), times the voltage from the third conductor to neutral.

It is easily demonstrated in the laboratory that one transformer of an energized three-phase star-star connected bank will collapse if a non-reactive load is connected between one line terminal and neutral; that is, the voltage of this transformer will fall to zero, and the other two will operate as in the open-delta connection under no-load.

It is equally simple to demonstrate that, by applying to one transformer of the energized star-star connected three-phase bank an e.m.f. from a single-phase generator, the voltage of this transformer may be made to assume any desired phase relation with respect to the voltage of the other two by merely adjusting the phase relation between the three-phase generator supplying the bank and the auxiliary generator. Among these possibilities is the reversed leg relation of Fig. 10, whose voltage relations are given in Fig. 12.

Digitized by Google

Whereas, to change the stored energy from that at B to that at C would require approximately

$$W_C = \frac{F_C (\phi_C - \phi_B)}{2}$$

for an increment of m.m.f. equal in magnitude to F_K.

It is seen from the diagram, Fig. 16, that $\phi_C - \phi_B$ is less than $\phi_K - \phi_B$ in magnitude,
and since

$$F_K = - F_C$$

$$W_C = \frac{F_C (\phi_C - \phi_B)}{2} \text{ is less than } W_K = \frac{F_K (\phi_K - \phi_B)}{2}$$

Hence, by both the theories of inertia and of least work, one of the transformers of the bank will reverse under the given conditions.

After the transformer flux has started from the point, B, toward the point, C, it will continue along the solid curve to a point, D, where the maximum m.m.f. is reached, because the impressed voltage is continuously applied. If F_D is equal to, or greater than, F_A, ϕ_D will be greater than ϕ_A because of the energy stored at the point, B, where $F = 0$; just as a separately excited generator will build up to higher value of voltage if it has some initial magnetism than it will if the flux is initially zero.

As the m.m.f. decreases, the flux will follow the solid curve from D to E, where ϕ_E is different from ϕ_B; so that, when the curve crosses the axis at E, the magnetomotive force, F, and the impressed voltage, E_1, do not pass through zero together. Consequently another reversal does not take place at the point, E, but the flux proceeds along the solid curve to the point, A', and thence to B', where another reversal takes place, returning the transformers to the relative positions of Figs. 9 and 11; and so on, reversing once in each fundamental cycle.

If the magnetomotive force or voltage waves contain harmonic components, the problem becomes more complicated; but the phenomena of periodic reversal will obtain when the impressed voltage and circuit conditions are such that the sum of the magnetomotive forces in the transformer passes through its zero value at the same instant as the impressed voltage.

Digitized by Google

The effect of this periodic reversal is to distort the voltages between line terminals and neutral as indicated by Figs. 11 and 12, and to introduce high harmonics because of the enormous magnetic densities to which transformers No. 2 and 3 are subjected.

Since the period of a total cycle of a reversing leg is twice as long as the fundamental frequency cycle of the impressed voltage, the phenomena are easily distinguishable by the presence of a second undertone, or "one-half" harmonic, in the voltages between line terminals and neutral.

Tests. It was attempted to simulate the conditions of Fig. 8 in the laboratory by using three similar 10 kv-a. transformers. Unstable conditions were obtained, but almost as soon as they appeared, arcs would develop in the condensers, producing large, very high-frequency effects that made the recording of oscillograms useless. The only condensers, that were available and at all suitable for the purpose, were one microfarad and two microfarad paraffin paper telephone condensers which apparently are not of sufficient dielectric strength. Other methods of obtaining the conditions are under consideration and will be tried as soon as possible.

Permanently Reversed Leg. The previous paper disposed of Case II by saying: "In the case with the stable unbalanced leg voltage condition, the neutral on the generator side of the bank assumed a fixed position with one leg reversed so that the voltages from two of the line conductors to neutral were approximately $\sqrt{7}$, (2.64), times the voltage from the third conductor to neutral.

It is easily demonstrated in the laboratory that one transformer of an energized three-phase star-star connected bank will collapse if a non-reactive load is connected between one line terminal and neutral; that is, the voltage of this transformer will fall to zero, and the other two will operate as in the open-delta connection under no-load.

It is equally simple to demonstrate that, by applying to one transformer of the energized star-star connected three-phase bank an e.m.f. from a single-phase generator, the voltage of this transformer may be made to assume any desired phase relation with respect to the voltage of the other two by merely adjusting the phase relation between the three-phase generator supplying the bank and the auxiliary generator. Among these possibilities is the reversed leg relation of Fig. 10, whose voltage relations are given in Fig. 12.

Digitized by Google

Of course, it must be noted that in these abnormal relations, the voltages on at least two of the transformers are abnormal because the vector difference of the leg voltages by pairs must always be the voltages between line terminals supplied by the three-phase generator. Hence, unless the tests are conducted at low voltages, dangerous voltages may arise or excessive exciting currents be demanded.

Causes. The question arises; what causes the transformer, under service conditions, to reverse to this abnormal position, Fig. 10, rather than assume the normal position of Fig. 9?

It is to be recalled that the abnormal phenomena arose upon charging the transformers and line together by closing the oil-switch on the generator side on the bank. As stated in the previous paper; "when charging the line the first time, leg *A* might reverse and continue reversed as long as the bank was excited. Switching off and on again might bring either leg *B* or leg *C* in reversed, and the reversed leg would be a stable condition as long as the transformers and line were energized. Occasionally, the three legs would come in without a reversed leg and conditions would be normal."

Subsequent to these tests, large accumulations of atmospheric electricity were observed on the line conductors under favorable seasonal conditions. With the line isolated throughout its length, an electrostatic voltmeter indicated differences of potential between line conductors and ground well up in the hundreds of volts. The electrostatic voltmeter had a range of only 80 volts and by the use of a series capacitance as multiplier the range could be raised to only something like 300 volts, but the potentials went well beyond this range. After grounding the line to drain the charge, the potentials would build up again in a few minutes. When neighboring bodies at or near the same horizontal plane become charged with atmospheric electricity, they all accumulate charges, which, though they may differ among themselves, give all these bodies potentials of the same algebraic sign with respect to the earth potential.

These considerations give foundation to the idea that, shortly after the three-phase alternating-current supply to the lines has been disconnected, the line conductors assume potentials of the same sign, say positive. True, under the conditions where these phenomena were discovered, Fig. 8, the line conductors were connected to grounded neutral transformer windings; but these windings and conductors themselves have resistance, so

Digitized by Google

that any drainage of the charge from conductors to ground necessitates a difference of potential, and all three conductors will continue to have positive potentials, however large or small.

When the oil switch is closed on the generator side of the bank, the inertia of the electric and magnetic fields tends to keep all three of the line conductors and transformer windings at positive potentials with respect to the earth, and the alternating currents start through the transformers in conformity with the initial conditions provided. After once started, the phenomena of the permanently reversed leg must continue unless, at some point in the cycle, the sum of the m.m.fs. in the reversed transformer passes through zero at the same instant as the impressed voltage, and the transformer reverses periodically as discussed above in connection with Fig. 16; or the even multiple frequency discussed below, or other yet undiscovered phenomena intervene and take precedence.

Pulsating Neutral. In the third case presented in the previous paper, the voltages between line conductors and ground contained even multiple frequency components. The original explanation of this phenomenon, though not contradicted, was questioned for want of clearness, and it will therefore be discussed here more fully.

It has been shown above that, when the transformers and line of Fig. 8, are energized by closing a switch on the generator side of the bank, one of the transformers may come in reversed on account of the initial potential of the line conductors (see Fig. 10); and that, if the sum of the magnetomotive forces in the reversed transformer does not later pass through its zero value at an instant when the impressed voltage passes through zero, there will be no opportunity for this transformer to reverse to its normal position, Fig. 9.

With transformer No. 1 reversed and Nos. 2 and 3 in the positions shown in Fig. 10, the fundamental component of voltage in Nos. 2 and 3 is 2.64 times that in No. 1. At low magnetic densities, this unbalance in the voltages apparently does not produce excessive unbalance of energy requirements among the three phases.

But as the voltage is increased, and the hysteresis loop of the transformers, Nos. 2 and 3, bends over, as in the outer loop of Fig. 27, page 52 of Steinmetz' "Theory and Calculation of Electric Circuits," the energy requirement in transformers Nos. 2 and 3 becomes enormous and thus with that of transformer No. 1 produces a gross unbalance.

Digitized by Google

Such being the case, it appears to be easier for the transformers to assume electrical relations as lateral edges of an inverted isosceles tetrahedron, Fig. 17, and thereby balance their energy requirements rather than assume the plane relations of Fig. 10. The edges of the base of the vector tetrahedron, Fig. 18, corresponding to Fig. 17, are the voltages between line terminals and conform to the limitations set by the generator. The vectors from the center of the base to the corners of the base are the fundamental components of the leg voltages.

Since the line conductors tend to stay at a positive potential with respect to the earth, and since the potential of the earth is constant, zero, the base of the tetrahedron must be lifted from the apex to its maximum position twice in each fundamental cycle. That is, the difference of potential between the apex

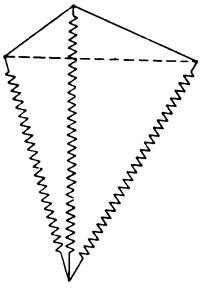


FIG. 17

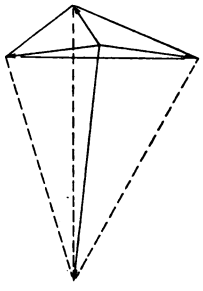


FIG. 18

(neutral of the transformers) and the center of the base (neutral of the line conductors) has two maxima and two minima for each fundamental cycle. Hence, the e.m.f., represented by a vector coincident with the altitude of the tetrahedron, has double frequency. The lateral edges of the tetrahedron do not represent the leg voltages because thus far it is only possible to represent single frequency variables by single vectors; and leg voltages are the vector differences between the double frequency vector (altitude of tetrahedron) and the fundamental frequency leg voltage components (center of base to corners of base).

While this explanation is perhaps still unsatisfactory in completeness, it is as far as it is possible to go at present. To sum it up: it seems that, at higher voltages and consequently higher flux densities, the pulsating neutral phenomena, evidenced by the double-frequency voltages between line terminals and neutral, are preferable to the permanently reversed leg phenomena

Digitized by Google

either because the former produce better balance in the energy requirements of the three units or because they make less total energy demand on the system, or both. The last is probably the actuality because in nature a symmetrical balance is usually requisite to maximum efficiency.

Auto-Transformers. In the fourth case, the high-voltage windings of a bank of transformers were connected star to ground the neutral of an otherwise isolated-neutral transmission line. The low-tension windings of the star-connected transformers were also star-connected with no-load, but neutral grounded to guard against induced potentials. Thus, in effect, these star-connected transformers were 1 to 1 auto-transformers or ironclad reactors connected between line conductors and ground.

The even harmonic phenomena were observed with this arrangement much as in the case of the star-star connected transformers discussed above. Further than this, the voltages between line terminals were approximately doubled by the presence of the auto-transformers.

At this time, nothing more can be said in explanation of the behavior of the auto-transformers than was said in the previous paper, except insofar as the above discussion of star-star connected transformers applies.

Sixth-Harmonic. Under the conditions where the second harmonic prevailed in the voltages between line conductors and ground, there was a large sixth harmonic component in the line and neutral currents, but there was no pronounced sixth harmonic component in the voltages between any line terminals of the transformers and neutral. This sixth harmonic current is, of course, the third harmonic of the second, and is required in the adjustment of the current in the ironclad circuit to meet the second harmonic voltage conditions.

Vibrations—Noises. After a consideration of the tremendous forces, electromotive and magnetomotive, to which the transformers were subjected during the phenomena discussed above, it seems almost like adding insult to injury to wonder why the transformers vibrated and emitted noises evidencing distress.

There can be no doubt that these vibrations and noises were the results of alternate repulsion and relaxation of stresses in the cores or coils, or both, and in their supports and braces, produced by the extremely large fluxes involved.

Laboratory Tests. In order to arrive at a rigid solution of the phenomena, it is naturally desirable to study them under labora-

Digitized by Google

tory conditions where the factors may be segregated and analyzed. With this object in view, it was attempted to simulate the conditions of Fig. 8, in the electrical laboratory here.*

It is obvious that to approach resonance between artificial line and transformers a considerable investment in condensers would be involved unless low-voltage, low-power transformers were used. On this basis, three 60-cycle, 10-watt, 1100/2200-110-volt potential transformers were selected. It was planned to connect them star-star, 1100 to 110-volts, thus putting the artificial line on the 110-volt side because high-voltage condensers were not available.

Meter measurements of the exciting admittances and susceptances from 30 volts up to 110 volts showed approximate equivalent exciting reactances ranging from 150 ohms to 350 ohms. In a rough way, this indicated that 20 microfarads per phase would be required for the tests. Sufficient paraffin paper condensers were provided.

While electrostatic voltmeters would have indicated the effective values, r.m.s., of the abnormal voltages, it is essential that the phenomena be studied by means of an oscillograph. An electrostatic oscillograph was not available, and an electromagnetic oscillograph makes so large an energy demand upon the circuit investigated than an oscillograph vibrator with its series resistance connected between artificial line conductor and neutral would have materially altered the character of the line. So it was decided to investigate the currents in the three transformers and line conductors by the insertion of 1.00-ohm shunts from which drop leads were connected to the oscillograph.

The apparatus was connected as shown in Fig. 8 except that no conductance was introduced other than that inherent in the paraffin condensers. The transformers were in one room near the generator, while, in order to expedite manipulation while operating the oscillograph, the condensers were placed in the oscillograph room about 75 feet from the transformers. This made it possible to insert the 1.00-ohm oscillograph shunts between the condensers and neutral, which latter was grounded for safety.

By an auxiliary potential transformer connected between supply lines, it was possible to keep track of the delta voltage impressed on the transformers.

Because of the excessive leg voltages anticipated, the tests

*University of California.

Digitized by Google

were started at very low impressed voltages, and at each voltage the capacitances between line conductors and ground were varied over the available range, balanced and unbalanced. Of course, the current from line conductors to neutral showed the usual transformer harmonics, but nothing abnormal occurred until 1940, (1120 $\sqrt{3}$), volts between wires was applied to the primary side.

With 1940 volts applied thus, the waves of line to neutral currents, on the visual tracing table of the oscillograph, began to travel, so to speak. That is, there was introduced a very low frequency component which had not been observed in previous tests. These phenomena came with only six microfarads between each line conductor and neutral. They would not exist at lower voltages with larger capacitance or at this voltage with smaller capacitance. This substantiates the theories that the phenomena depend upon a critical point in the variation of the exciting reactance of the transformer, and upon the inter-relation of the line susceptance and transformer reactance.

The records of these phenomena are submitted in oscillograms, *T*-1, *T*-2 and *T*-3.

Noting the 60-cycle (same frequency as supply) timing wave on oscillogram *T*-3, vibrator 1 and the current from line conductor 3 to neutral, shown on vibrator 3 of *T*-3; it is observed that, for any two successive 1/60-second intervals the latter wave does not repeat itself but undergoes a consistent alteration. In fact, there appear to be no two identical 1/60-second sections in the whole record, *T*-3, which covers more than 1/6 second. This is consistent with the instability and apparently very low frequency alternation observed on the oscillograph tracing table before the record was taken. Also, the progressive alternation of the wave, compared to the stable timing wave from the same source, indicates conclusively that the currents in the line, and thereby the voltages from line to neutral, are in considerable measure independent of the wave shape and frequency of the impressed supply voltage when the grounded neutral star-star connection is employed in transmission under suitable conditions.

The tests could not be carried materially beyond 1940 volts impressed because the potential transformers were then carrying 1.6 amperes each and were doubtless withstanding excessive voltages. They became so hot that the insulation filler was softened.

Digitized by Google

Next, series resistances up to approximately 200 ohms each were inserted in the line conductors. These had no observable effect on the production of the phenomena. They probably reduced the magnitudes of the currents somewhat but even this was not noticeable on the oscillograph.

It was suggested that admittances connected directly between line conductors might have some effect. Some different combinations of delta-admittances alone, and of delta- and Y-admittances together were tested. The phenomena depended as before upon the magnitude of the Y-admittances and upon the impressed voltage. The oscillograms, *T*-4, *T*-5 and *T*-6 are the main records. They show substantially the same variation of the line to neutral currents as oscillograms *T*-1, *T*-2 and *T*-3. The conclusion to be drawn is that the admittances connected directly between line conductors, though necessarily affecting the line to neutral currents to some extent, are not essential to the production of the phenomena of instability.

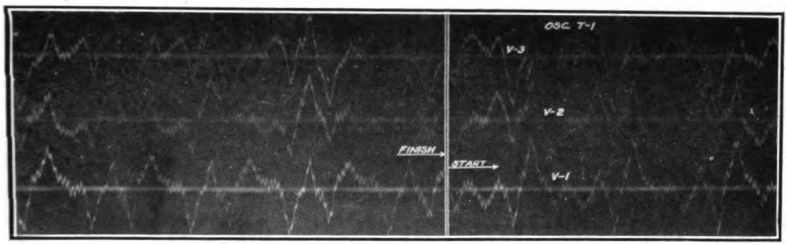
Conclusion

While the foregoing can not be thought of as expressing the conclusive solution of these most interesting phenomena, it is felt that the recent work has resulted in substantial progress. In reviewing the subject, it is gratifying to note that the theory still stands in essence as originally outlined though there have been many additions and adjustments which, however, have served only to make the factors more consistent.

Since the original tests were made, the writer has been told of a case where, in starting up an auxiliary plant, inexplicable vibrations in the transformers were observed under conditions similar to those involved in these experiments. It happened on a grounded neutral 100,000-volt system, where the grounding transformers usually had secondary or tertiary deltas. The bank at this auxiliary station had no such delta. In starting up this time, the line was energized from this station, to be synchronized at a distant station. As soon as the distant station, with its tertiary delta-star grounded neutral bank, was connected to the line, the vibrations in the transformers at the auxiliary station ceased.

Since then, the writer also noted the remark of Mr. Bernard Price in the latter's recent discussion of the report of the Transmission Committee of the American Institute of Electrical

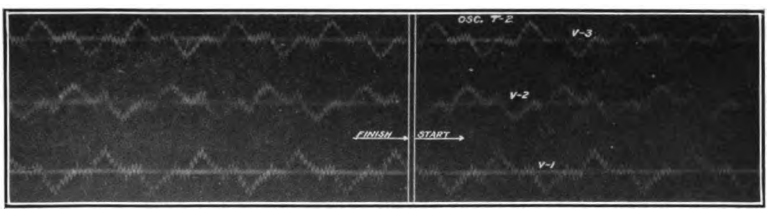
Digitized by Google



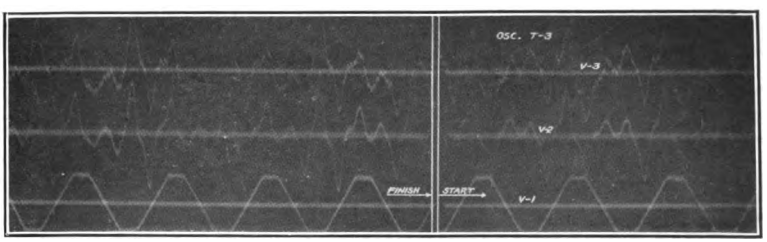
T-1 LINE TO NEUTRAL CURRENTS IN ALL THREE PHASES, 1940, (1120 $\sqrt{3}$) VOLTS BETWEEN LINE TERMINALS IMPRESSED ON TRANSFORMERS,

Approximately 6 microfarads per phase, line to neutral,

V-1 Current of phase 1,
V-2 Current of phase 2,
V-3 Current of phase 3.



T-2 SAME AS *T*-1 EXCEPT 1820, (1150 $\sqrt{3}$), VOLTS BETWEEN LINE TERMINALS IMPRESSED ON TRANSFORMERS



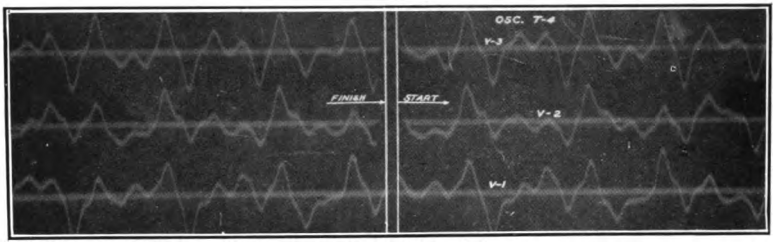
[ROBINSON]

T-3 CONDITIONS SAME AS FOR *T*-1

V-1 Fundamental (60-cycle) timing wave,
V-2 Neutral current,
V-3 Current of phase 3.

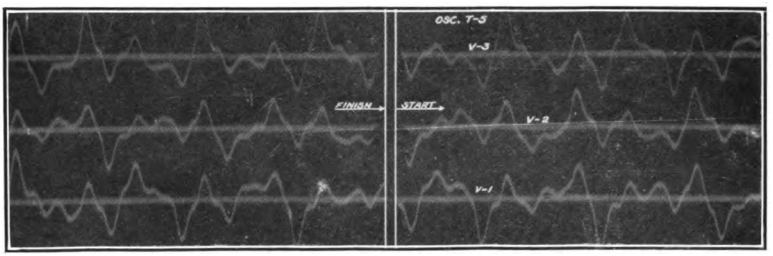
Digitized by Google

Digitized by Google



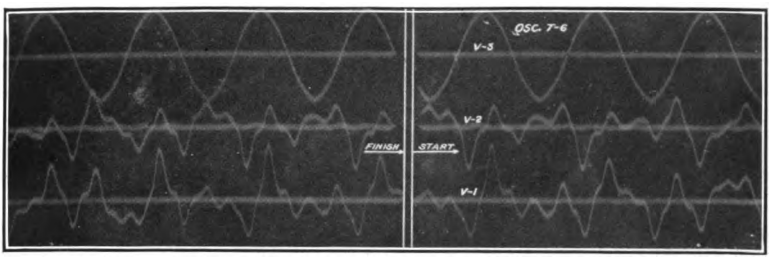
T-4 2130, (1230 $\sqrt{3}$), VOLTS BETWEEN LINE TERMINALS IMPRESSED ON TRANSFORMERS
ADMITTANCES BETWEEN LINE CONDUCTORS AND NEUTRAL AND BETWEEN LINE CONDUCTORS

V-1 Current, phase 1 to neutral, 1.59 amperes, r.m.s.
V-2 Current, phase 2 to neutral, 1.60 amperes, r.m.s.
V-3 Neutral current, 3.50 amperes, r.m.s.



T 5 CONDITIONS SAME AS FOR *T*-4 EXCEPT 2110 VOLTS BETWEEN LINE TERMINALS IMPRESSED ON TRANSFORMERS

V-1 Current, phase 1 to neutral, 1.50 amperes, r.m.s.
V-2 Current, phase 2 to neutral, 1.50 amperes, r.m.s.
V-3 Current, phase 3 to neutral, 1.50 amperes, r.m.s.



[ROBINSON]

T-6 CONDITIONS SAME AS FOR *T*-4 EXCEPT 2120 VOLTS BETWEEN LINE TERMINALS IMPRESSED ON TRANSFORMERS

V-1 Current, phase 1 to neutral, 1.55 amperes, r.m.s.
V-2 Current, phase 2 to neutral, 1.55 amperes, r.m.s.
V-3 Fundamental (60-cycle) timing wave.

NOTE: Line current from each transformer, including currents between lines and currents from line conductors to neutral, ranged from 2.00 to 2.10 amperes, r.m.s., increasing with increased voltage.

Digitized by Google

Digitized by Google

Engineers.* In the second from the last paragraph on page 596, Mr. Price says: "With the neutral of the 40,000-volt system earthed at two distant points, we found the presence of a comparatively large amount of even harmonics, the sixth being predominant and over 20 per cent of the fundamental in value and in phase with it." There can be little doubt that, by the use of the oscillograph, he has discovered much the same phenomena as have been here discussed.

An attempt to reach Mr. Price, in South Africa, by letter dated in December 1916 has probably been interrupted by shipping conditions. No reply has been received up to April 24, 1917.

These two cases observed in commercial practise, one in South Africa and one in the United States, coupled with the facts that our original tests were conducted on two dissimilar banks of transformers, and that certain of the associated phenomena were produced in a bank of three 10-watt potential transformers in the laboratory, are, at least, indications that the phenomena were not locally peculiar to special conditions as might be thought at first sight.

The writer believes that a system of notation, similar in its application to that of the present plane vector complex quantity notation used in expression of single-frequency phenomena, would be eminently useful in handling the above phenomena of instability. It hardly seems possible that there is no simple means available for representing in one diagram multiple-frequency variables either separately or combined. In Fig. 18, an attempt has been made toward an extension; but it has not gone very far, and difficulties would obviously be encountered if an attempt were made to include the third, sixth and a few other harmonics. Probably vectors in three-dimensional space will not suffice.

In closing, the writer desires to acknowledge his indebtedness to many engineers who, by their criticisms and suggestions, have encouraged the work; and for the facilities placed at his disposal for conducting the tests and experiments.

*TRANS. A. I. E. E., Vol. XXXV, 1916, pp. 590–597.

Digitized by Google

To be presented at the 335th Meeting of the American Institute of Electrical Engineers, New York, December 14, 1917.

Copyright 1917. By A. I. E. E.

(Subject to final revision for the Transactions.)

MAGNETIC FLUX DISTRIBUTION IN ANNULAR STEEL LAMINAE

BY A. E. KENNELLY AND P. L. ALGER

ABSTRACT OF PAPER

The distribution of alternating magnetic flux density in ring laminae is studied experimentally. It is found to differ materially at different radii, not only in root-mean-square magnitude, but also in wave form. The reasons for this distortion are discussed.

IT IS well known that when a circular steel lamina, of the simple geometrical form shown in Figs. 1 and 4, is subjected to a circumferential alternating m.m.f., by the application of a ring winding, the magnetic flux density in the lamina is not constant over the cross section, but varies with the distance from the midplane. The flux density is greatest at the surfaces and is a minimum at the midplane, owing to what is commonly called "skin effect," or magnetic screening due to superficial eddy currents. This variation of flux density may be called "depth variation." The experiments here reported were undertaken to ascertain whether the flux density in the plane of the lamina likewise varied. If "edge effect" were present, the flux density would be greatest at the inner and outer edges, and would reach a minimum at the mid radius. Such variations of flux density may be called "radial variations." The experiments have shown that there is a very marked radial variation of flux density in such laminae, and also a very marked difference in the wave form of alternating magnetic flux density at different radial belts; but these variations are to be attributed, for the most part, to variations in the permeability μ of the metal under the different values of $\mathfrak{H}$ at the different radii, the "edge effect" or lateral magnetic screening being small in comparison therewith.

The m.m.f. of the ring winding has of course one and the same value in all of the circumferential belts. The same ampere turns or gilberts act on the outer edge as on the inner edge. The gilberts per cm. are therefore less at the outer than at the inner edge. This excess of magnetic intensity $\mathfrak{H}$ towards the inner edge

Manuscript of this paper was received October 25, 1917.

Digitized by Google

tends to create a greater flux density at that edge. But the permeability varies with $\mathfrak{H}$ in such a manner that the crowding at the inner edge is exaggerated for low magnetic densities. Moreover, the wave form of the alternating magnetic flux is considerably distorted at the edges from that of the total flux in the lamina.

These distortions of radial flux density, although very striking, are not entirely new. Kapp has called attention to the fact that the mean flux density in the laminated core of a dynamo armature, obtained by dividing the total flux by the armature cross section, is not the same as the arithmetical mean of the flux densities at the inner and outer radii.[1] Niethammer[2] has also computed the flux densities at different radii of a laminated ring transformer, and has pointed out that at low average densities, the distribution, with a permeability assumed constant, must be

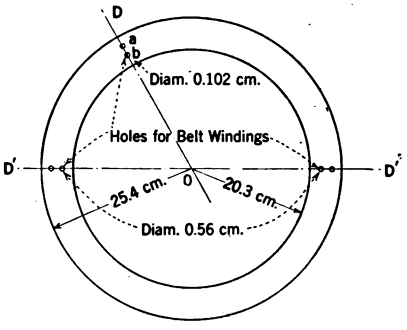


FIG. 1—SILICON STEEL LAMINA

markedly different from that with permeability varying with $\mathfrak{H}$ in the ordinary way. So far as we are aware, however, the matter has not been investigated experimentally, and the necessarily accompanying distortion in magnetic wave form has not been noticed or referred to.

Laminae Tested. The laminae were annular stampings of high-silicon steel. The external diameter of these stampings was 50.8 cm. (20 in.), the internal diameter was 40.6 cm. (16 in.) and their thickness 0.355 mm. (0.014 in.). These were standard blank stampings of best grade transformer steel. The material is characterized by high resistivity (52000 absohm-cm.), with a

1. Dynamomaschinen für Gleich-und Wechselstrom, 3rd Edition, p. 254, by G. Kapp.

2. Sammlung Elektrotechnischer Vorträge, Vol. II, Part 11-12. Magnetism, pp. 10-12, by F. Niethammer.

Digitized by Google

low temperature coefficient of the same, and a high initial permeability.

A laminated core was made up of 25 of the above stampings, using an insulating layer of paper 0.076 mm. (0.003 in.) between laminae. The resulting core had an average thickness of 1.2 cm. (0.47 in.) The weight of steel in the core was 4.78 kg. (10.5 lb.)

As is indicated in Fig. 1, small holes *a*, *b*, were drilled through the core, in a diametral line *O D*, and perpendicular to the plane of the laminae. The diameter of each hole was 1.02 mm. (0.040 in.) Figure 2 gives in greater detail the distances between these holes, and the edges of the core. The object of the holes was to divide the core radially into three concentric annular belts,

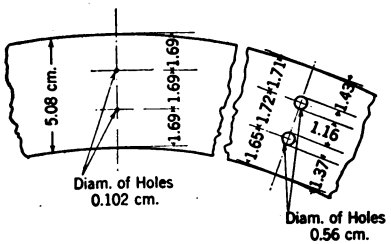


FIG. 2—SHOWING POSITIONS OF HOLES FOR BELT WINDINGS

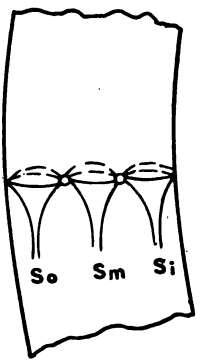


FIG. 3—BELT WINDINGS

the magnetic flux in each of which could be separately determined by the aid of suitable windings through the holes. Four fine insulated copper wires were passed through each hole to form a winding of two turns (Fig. 3) around each annular belt. By the use of a Drysdale-Tinsley potentiometer, the voltage induced in these two-turn windings could be measured at all the frequencies employed. In order, however, to obtain oscillograms of the induced alternating-voltage wave forms, it was found necessary to employ windings of more numerous turns, and two sets of larger holes (diam. 5.6 mm. or 0.22 in.) to receive these windings, were drilled on another diametral line *D' D'*, as shown in Fig. 1. Twenty turns were used in these larger belt windings.

A primary single-layer winding was distributed around the core, consisting of 450 turns of d.c.c. copper wire No. 19 A. W. G.

Digitized by Google

(bare diam. 0.91 mm.) divided into six coils *aa'*, *bb'*, Fig. 4, averaging 75 turns each. In addition, two secondary coils *cc'*, *cc'*, of 75 turns each, were applied at diametrically opposite sectors, around all the laminae forming the core.

The sources of primary impressed voltage were two three-phase alternators, specially designed by Prof. C. A. Adams, to deliver a close approximation to a sinusoidal wave. One of these generators was used up to a frequency of 100 ~, and the other for frequencies from 100 ~ to 800 ~. The electrical connections are indicated in Fig. 4.

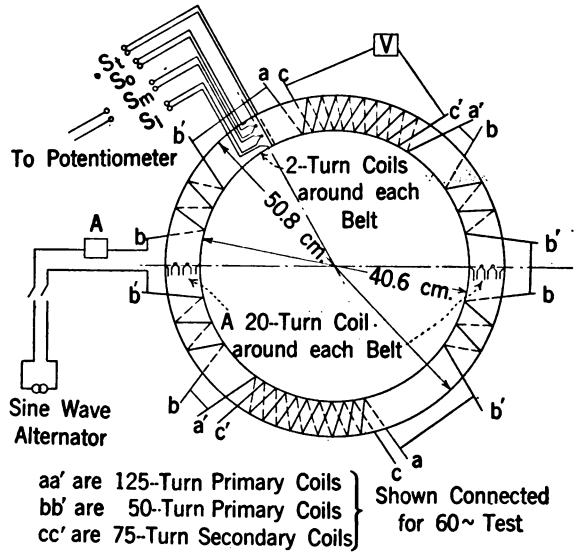


FIG. 4

METHODS OF TESTING

A-C. Tests. The method of testing by alternating currents consisted in impressing a sinusoidal e.m.f. on the primary winding *bb'* Fig. 4, of the desired frequency, so as to produce a total flux in the core of sinusoidal wave form. The average maximum cyclic flux density generated in the core was then deduced from observations of the voltmeter, and also from Drysdale potentiometer readings on a single secondary turn S_t around the core. The total flux in the core was found to be substantially sinusoidal, as shown in Fig. 5, which is an oscillogram of the e.m.f. induced in S_t. It was soon found, however, that the fluxes in the three annular belts were nonsinusoidal. The three fundamental com-

ponents of the inner, middle and outer belt e.m.fs from the inner, middle, and outer secondary coils S_i, S_m and S_o respectively, were measured on the Drysdale potentiometer, as is indicated in Tables I, II, and III for the frequencies of 60, 340 and 696 ~.

Belt Potentiometer Tests. The results arrived at in the foregoing tables show that the maximum fundamental flux densities in the three belt paths are very different, especially towards low densities. The cross sections of the three belt paths, as determined by the positions of the two small holes through the core, were equal within 3 per cent; but the outside belt carried at $B_{max.} = 1000$, 340~, only 24 per cent of the total flux instead of 30.9 per cent on the basis of constant permeability. On the other hand, the inside belt carried 45 per cent. The middle belt carried 31 per cent. The results for three different frequen-

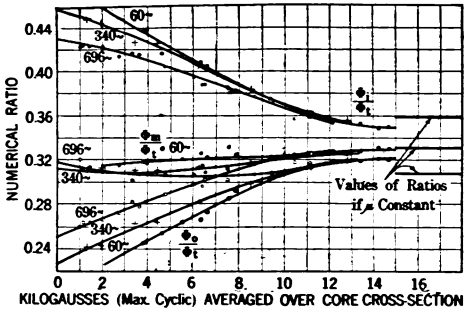


FIG. 6—VARIATION OF FLUX DISTRIBUTION WITH DENSITY

cies are shown at various flux densities averaged over the entire core, in Fig. 6. The curves show that the greatest distortion from uniformity in the three annular belt fluxes occurs at the lowest flux density, and it diminishes as the density increases. At the highest flux density of 13 kilogausses (maximum cyclic averaged over the entire cross section) the three belt flux densities are more nearly in inverse proportion to the lengths of the respective annular flux paths. The reasons for this non uniform distribution at low flux densities will be considered later on.

Belt Oscillograms. Figs. 7, 8 and 9 are oscillograms of the secondary e.m.f. induced in windings of 20 turns each on the inner, middle, and outer belts, S_i, S_m and S_o respectively, taken at the same time as Fig. 5. The oscillograph was a Duddell vibration galvanometer tuned to about 2000 ~. This

Digitized by Google

TABLE I.

RESULTS OF TESTS AT THE FREQUENCY OF 60 CYCLES PER SECOND.

Volts	Potentiometer Readings				$\mathfrak{B}_{max}$						$\frac{\mathfrak{B}o}{\Sigma\mathfrak{B}}$	$\frac{\mathfrak{B}m}{\Sigma\mathfrak{B}}$	$\frac{\mathfrak{B}i}{\Sigma\mathfrak{B}}$	$\frac{\Sigma\mathfrak{B}}{3\mathfrak{B}t}$
t_{75}	o_2	m_2	i_2	$t_1/0°$	o	m	i	t_1	t_{75}	t				
I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV
3.61	0.0234\0°.9	0.0302\0°.5	0.0418\1°.3	0.0477	2920	3770	5210	3970	4000	3980	0.246	0.317	0.437	0.998
4.23	0.0290\1°.3	0.0377/0°.1	0.0474/1°.4	0.0558	3620	4700	5910	4640	4690	4660	0.254	0.330	0.416	1.019
5.65	0.0405\4°.9	0.0497/0°.3	0.0623/1°.9	0.0771	5050	6200	7760	6420	6260	6370	0.266	0.326	0.408	0.996
7.15	0.0555\3°.5	0.0617/0°.2	0.0729/3°.0	0.0950	6920	7700	9100	7900	7930	7910	0.292	0.325	0.383	1.000
8.50	0.0685\3°.5	0.0726/0°.8	0.0844/2°.1	1.139	8540	9050	10530	9470	9430	9460	0.303	0.322	0.375	0.990
10.25	0.0854\4°.5	0.0886/0°.2	0.0981/3°.2	1.348	10660	11060	12250	11200	11370	11260	0.313	0.326	0.361	1.006
11.1	0.0943\3°.7	0.0969/0°.2	0.1041/3°.0	1.461	11780	12100	13000	12150	12310	12200	0.319	0.328	0.353	1.007
12.27	0.1015\3°.0	0.1045/0°.5	0.1125/2°.0	1.612	12650	13030	14020	13410	13610	13450	0.319	0.328	0.353	0.985
13.05	0.1104\1°.8	0.1140/0°.7	0.1199/2°.4	1.709	13780	14220	14950	14210	14480	14250	0.321	0.331	0.348	1.003
13.9	0.1123\2°.0	0.1159\1°.9	0.1232\1°.4	1.765	14010	14460	15380	14680	15400	14700	0.320	0.330	0.350	0.994
3.42	0.0228/0°.3	0.0296/0°.5	0.0406\0°.2	0.0460	2845	3695	5070	3820	3790	3810	0.245	0.318	0.437	1.017
5.95	0.0435\2°.4	0.0512\0°.3	0.0644/1°.9	0.0803	5430	6390	8040	6670	6600	6650	0.273	0.322	0.405	0.998
6.80	0.0524\3°.0	0.0608\1°.8	0.0704/1°.7	0.0916	6540	7590	8790	7620	7550	7600	0.285	0.331	0.384	1.006
4.92	0.0351\1°.7	0.0425/0°.2	0.0551/1°.4	0.0666	4370	5300	6860	5540	5460	5510	0.264	0.321	0.415	1.001

Col. I indicates the induced secondary e.m.f., by voltmeter in the 75-turn over-all winding.
Cols. II, III, IV, give the two-turn belt winding e.m.fs. by a-c. potentiometer, on outer, middle and inner belts respectively.
Col. V gives the single-turn over-all e.m.f. by potentiometer.
Cols. VI, VII, VIII give the corresponding computed values of flux density, max. cyclic gausses, in the outer, middle, and inner belts.
Col. IX gives the computed average flux density by potentiometer, X that by voltmeter in Col. I.
Col. XI gives the accepted average flux density (max. cyc. gausses) allowing weights to IX and X.
Cols. XII, XIII, and XIV give the respective ratios of outer, middle, and inner belt fluxes to the total flux.
Col. XV gives the ratio of the sum of the belt fluxes to the total flux as a check. It should be unity throughout.

Digitized by Google

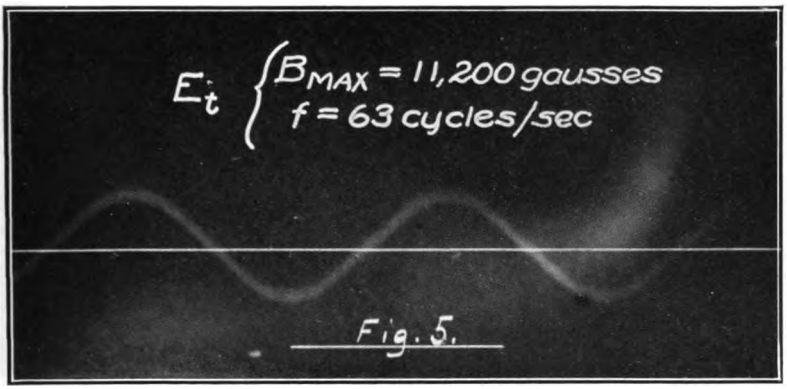


Fig. 5.

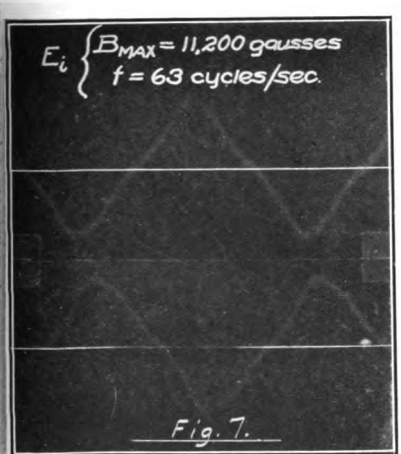


Fig. 7.

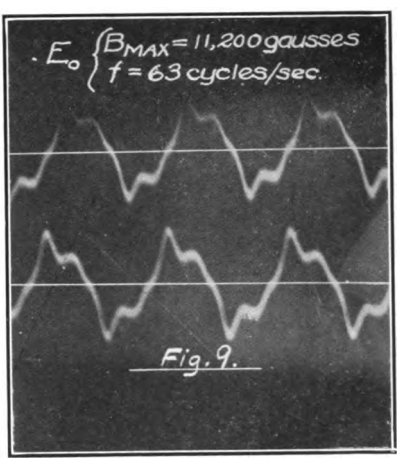


Fig. 9.

[KENNELLY]

Digitized by Google

Digitized by Google

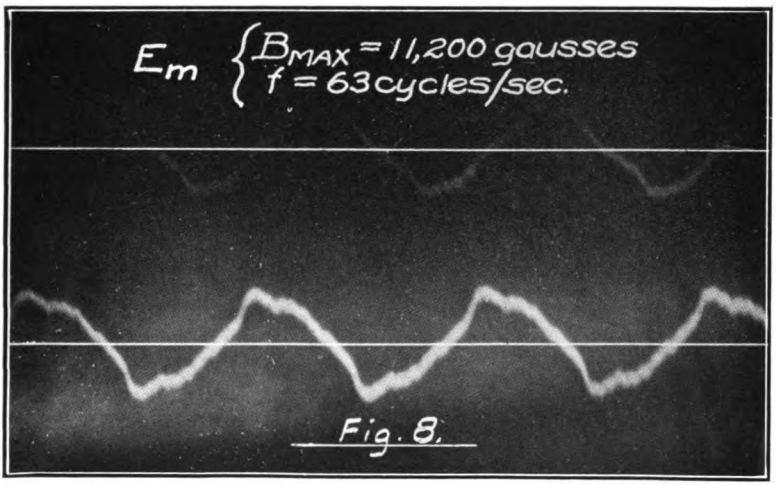


Fig. 8.

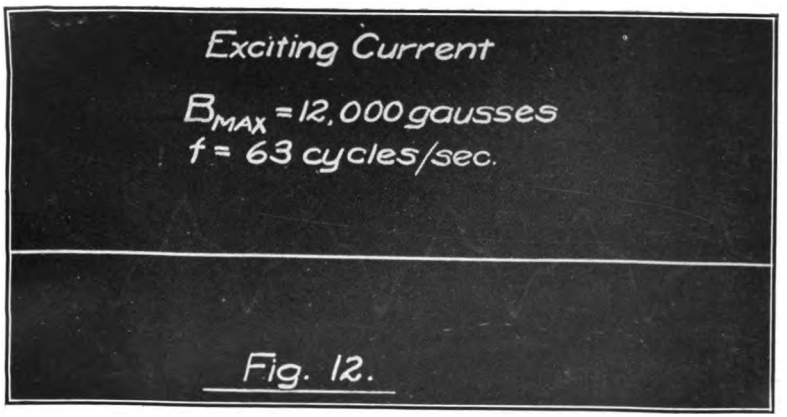


Fig. 12.

[KENNELLY]

Digitized by Google

Digitized by Google

TABLE II.

RESULTS OF TESTS AT THE FREQUENCY OF 340 ~

E. m. f. by voltmeter	E. M. F. by Potentiometer				$\mathfrak{B}_{max}$						$\frac{\mathfrak{B}o}{\Sigma\mathfrak{B}}$	$\frac{\mathfrak{B}_m}{\Sigma\mathfrak{B}}$	$\frac{\mathfrak{B}i}{\Sigma\mathfrak{B}}$	
t_{75}	o_2	m_2	i_2	$i_1/0°$	o	m	i_1	i_1	t_{75}	t				
6.5	0.0463/7°.0	0.0594/2°.0	0.0858\2°.1	0.0916	1620	1310	1885	1345	1270	1320	0.242	0.311	0.447	1.068
10.0	0.066 /5°.4	0.085 /0°.9	0.121 \3°.2	0.135	1455	1875	2660	1980	1960	1973	0.243	0.313	0.444	1.012
18.0	0.123 /3°.5	0.146 \0°.8	0.200 \2°.7	0.234	2710	3210	4400	3440	3520	3465	0.263	0.311	0.426	0.994
23.0	0.160 /4°.2	0.188 /0°	0.257 \1°.8	0.301	3520	4140	5660	4420	4500	4445	0.264	0.311	0.425	1.000
32.2	0.246 /2°.6	0.275 /1°.0	0.352 /1°.2	0.425	5410	6050	7800	6240	6310	6270	0.281	0.314	0.405	1.023
43.8	0.351 /0°.1	0.371 \3°.0	0.451 /2°.4	0.586	7720	8160	9920	8600	8580	8590	0.299	0.317	0.384	1.001
57.8	0.479 \0°.8	0.494 \3°.0	0.552 /2°.9	0.760	10570	10900	12180	11180	11300	11220	0.314	0.324	0.362	0.999
66.0	0.550 \0°.6	0.560 \2°.9	0.614 /3°.0	0.872	12120	12340	13530	12830	12900	12850	0.319	0.325	0.356	0.985

Digitized by Google

TABLE III

RESULTS OF TESTS AT THE FREQUENCY OF 696 ~

E. M. F. by voltmeter	E. M. F. by Potentiometer				$\mathfrak{B}_{max}$						$\frac{\mathfrak{B}o}{\Sigma\mathfrak{B}}$	$\frac{\mathfrak{B}m}{\Sigma\mathfrak{B}}$	$\frac{\mathfrak{B}i}{\Sigma\mathfrak{B}}$	$\frac{\Sigma\mathfrak{B}}{3\mathfrak{B}_t}$
t_{75}	o_2	m_2	i_2	$t_1/0°$	o	m	i	t_1	t_{75}	t				
10.7	0.071/2°.8	0.087\0°.7	0.115\3°.0	0.144	765	935	1240	1030	1020	1025	0.260	0.318	0.422	0.956
12.2	0.083/3°.3	0.098\0°.8	0.133\3°.7	0.159	890	1060	1430	1140	1170	1140	0.264	0.313	0.423	0.988
15.3	0.102/3°.2	0.122\1°.0	0.164\4°.4	0.200	1100	1310	1760	1435	1460	1440	0.264	0.314	0.422	0.966
21.4	0.148/2°.3	0.174\1°.1	0.235\3°.1	0.284	1590	1870	2530	2030	2040	2035	0.266	0.312	0.422	0.982
29.0	0.209/2°.3	0.242\1°.5	0.317\2°.6	0.390	2250	2600	3410	2780	2770	2780	0.272	0.315	0.413	0.991
....	0.262/3°.2	0.280\0°.6	0.386\1°.8	0.466	2820	3010	4150	3340	....	3340	0.282	0.302	0.416	0.996
38.4	0.279/2°.9	0.309\0°.9	0.417\2°.1	0.508	3000	3320	4490	3650	3670	3660	0.278	0.307	0.415	0.984
50.4	0.386/2°.4	0.410\1°.2	0.541\1°.4	0.670	4150	4410	5810	4800	4810	4800	0.289	0.307	0.404	0.998
60.9	0.504/1°.4	0.518\1°.2	0.668/0°.2	0.846	5420	5570	7190	6070	5810	6070	0.298	0.307	0.395	0.999
66.4	0.568/0°.8	0.535\2°.0	0.698/1°.0	0.901	6110	5750	7510	6440	6350	6440	0.297	0.315	0.388	1.002
67.7	0.568/1°.0	0.656\2°.0	0.711/0°.8	0.917	6110	5980	7650	6570	6470	6570	0.309	0.303	0.388	1.001
77.6	0.656/0°.9	0.635\2°.7	0.809/2°.2	1.058	7050	6830	8700	7550	7420	7550	0.302	0.312	0.386	0.998
90.6	0.772\0°.1	0.749\2°.2	0.919/2°.1	1.230	8300	8050	9880	8780	8660	8780	0.316	0.307	0.377	0.998
97.2	0.858\0°.2	0.823\4°.6	0.990/3°.1	1.334	9220	8850	10640	9530	9290	9530	0.321	0.308	0.371	1.004
107.8	0.944\0°.6	0.926\3°.6	1.070/3°.2	1.469	10150	9950	11150	10520	10300	10520	0.325	0.318	0.357	0.990
114.7	1.009\0°.5	0.985\4°.3	1.120/3°.6	1.568	10840	10600	12040	11200	10960	11200	0.324	0.317	0.359	0.997

Digitized by Google

instrument was selected for the purpose, instead of the ordinary oil-damped oscillograph because of its sensitiveness, the current required to operate it being only about 10 milliamperes r. m. s. It was desirable to keep the oscillographic current and ampere turns as low as possible, so as not to distort the voltages and flux distributions among the three belts. With 20 secondary belt turns, and 10 milliamperes, this secondary m.m.f. would be only 0.2 r. m. s. ampere-turn per belt. The resistance of the instrument itself was 130 ohms, and an extra resistance of 57 ohms was included in its circuit. The effect of this counter m.m.f. of 0.2 ampere-turn was to distort somewhat the wave

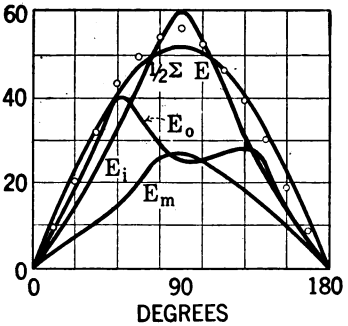


FIG. 10—REPRODUCTION OF BELT OSCILLOGRAMS TO A UNIFORM SCALE AND THE EQUIVALENT SINUSOIDAL TOTAL E.M.F. SUMMATION ORDINATES ARE SHOWN BY THE CIRCLES

Fourier analaysis of flux waves in Fig. 10.

$$E_0 = 34.5 \sin\theta + 5.3 \sin 3\theta - 4.2 \sin 5\theta + \\ + 3.1 \cos\theta - 2.9 \cos 3\theta + 0.4 \cos 5\theta +$$

$$E_m = 23.8 \sin\theta - 2.4 \sin 3\theta + 0.9 \sin 5\theta + \\ - 1.5 \cos\theta + 1.0 \cos 3\theta + 0.6 \cos 5\theta +$$

$$E_i = 47.7 \sin\theta - 8.6 \sin 3\theta + 2.0 \sin 5\theta + \\ + 0.2 \cos\theta + 0.1 \cos 3\theta - 0.4 \cos 5\theta +$$

$$E_0 + E_m + E_i = 106.0 \sin\theta - 5.7 \sin 3\theta - 1.3 \sin 5\theta + \\ + 1.8 \cos\theta - 1.8 \cos 3\theta + 0.6 \cos 5\theta +$$

shape of flux in each of the three belts. This distortion should however be of the same character for each belt, and if the three belt fluxes were the same, the three belt oscillograms should be substantially the same.

The oscillograms in Figs. 5, 7, 8 and 9 are, however, markedly different, showing that the three belt fluxes differ not only in their maxima, but also in their wave form. Moreover, in order to estimate the amount of distortion in the belt oscillograms due to counter m.m.f., all of the oscillograms were repeated with only one-third of the resistance in the secondary circuit, so as to increase the distorting counter m.m.f. about three times. The upper curves in Figs. 7, 8 and 9 were taken with 0.2 ampere turn

Digitized by Google

of counter m.m.f., while the lower curves were thus taken with 0.6 ampere turn of counter m.m.f. It will be seen that since the differences between the upper and lower curves in each case are not large, the differences between the upper curves and corresponding curves unaffected by counter m.m.f. would be still less.

As a further check on the belt oscillograms, they have been copied to a uniform scale, as shown in Fig. 10, and then combined by addition, as indicated by the small circles. The best representative sine wave is drawn on the same figure for comparison, the

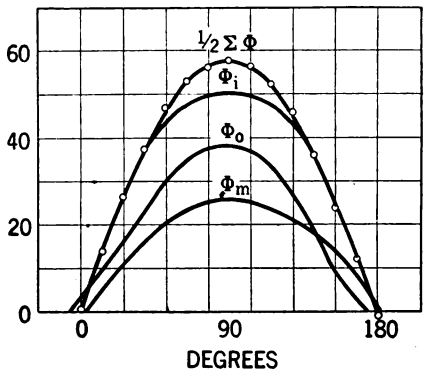


FIG. 11—FLUX WAVES DERIVED FROM INTEGRATION OF THE BELT E.M.F. WAVES IN FIG. 10—ALSO THE SINUSOIDAL TOTAL FLUX INTO WHICH THEY COMBINE.

Fourier analysis of flux waves in Fig. 11.

$$\phi_0 = 36.6 \sin\theta - 2.4 \sin 3\theta - 0.8 \sin 5\theta + \\ + 3.2 \cos\theta + 0.3 \cos 3\theta - 0.4 \cos 5\theta +$$

$$\phi_m = 26.6 \sin\theta + 0.8 \sin 3\theta + 0.1 \sin 5\theta + \\ - 1.6 \cos\theta - 0.4 \cos 3\theta + 0.2 \cos 5\theta +$$

$$\phi_i = 53.2 \sin\theta + 2.6 \sin 3\theta + 0.5 \sin 5\theta + \\ + 0.1 \cos\theta - 0.04 \cos 3\theta - 0.1 \cos 5\theta +$$

$$\varphi_0 + \varphi_m + \varphi_i = 116.4 \sin\theta + 1.0 \sin 3\theta - 0.2 \sin 5\theta + \\ + 1.7 \cos\theta - 0.14 \cos 3\theta - 0.3 \cos 5\theta +$$

total flux being substantially sinusoidal as in Fig. 5. The deviations of the circles from this sine wave are sufficiently small to be attributable to errors in reproducing the oscillograms of Figs. 7, 8 and 9, the amplitudes of which were actually only 1 to 2 cm.

The Fourier analysis of the curves E_o, E_m and E_i are indicated in Fig. 10. The harmonics beyond the fifth are negligible throughout. It will be seen that E_o contains a 17 per cent triple and a 12 per cent quintuple component. E_m has a 11 per cent triple component. E_i has an 18 per cent triple component.

Digitized by Google

In the summation of the three waves, the harmonics almost disappear except for a residual 6 per cent triple component.

On integrating the curves of Fig. 10, so as to reduce the induced e.m.f.s. to their equivalent magnetic fluxes, the curves of Fig. 11 are obtained. As naturally follows such a process of integration, the resulting flux curves are smoother than the original oscillographic e.m.f. curves. The agreement of their sum with a sine wave is accordingly better. The largest belt flux is clearly the inner one ϕ_i. It would be expected that the outer belt flux should be the smallest; but as is shown in Fig. 2, the width of the middle belt was somewhat unduly small. Figs. 10 and 11 are thus in substantial accordance with Fig. 5, in showing that the total flux through the core was sinusoidal, although the individual belt fluxes were far from sinusoidal.

The corresponding Fourier analysis of the curves in Fig. 11 appear beneath it. They are in substantial conformity with the e.m.f. wave analysis of Fig. 10.

The results, appearing in the tables and presented graphically in Fig. 6, also indicate that the numerical sums of the fundamentals of the three belt e.m.fs. are equal to the e.m.fs. of the turns around the entire core. Moreover in Fig. 6 the sums of the ordinates on the belt curves remain equal to unity throughout the entire range of averaged flux density.

Reasons for the Distortions in the Belt Flux Densities

It is well known that in the primary winding of an excited transformer under no load, the exciting current is nonsinusoidal when the impressed e.m.f. is sinusoidal; firstly because of the varying permeability, and secondly because of hysteresis. The current wave under ordinary conditions is peaked. An oscillogram of the primary current at 63 $\sim$ and 12,000 gausses (max. cyc.) appears in Fig. 12. The peak is to be ascribed to the change of permeability of the iron during the cycle. Assuming a total flux that is sinusoidal, the exciting current at each moment must conform to the $\mathfrak{H}$-$\mathfrak{B}$ cycle for the entire core. If the various belt paths in the laminae had equal lengths, they would share the flux equally, neglecting skin effects. Actually, however, the inner belt paths are shorter, and these therefore tend to carry a larger share of the flux. This in turn alters the reluctance, because the permeability depends upon the density. At low densities, the tendency is to increase the flux of the inner belt paths yet more, because the permeability at first increases

Digitized by Google

with flux density. At high densities, on the contrary, the tendency is in the opposite direction. Consequently, at low densities, the flux in the inner belts tends to be very different from that in the outer belts, as is shown by Fig. 6. At high densities, however, the permeances of the different belts are more nearly uniform, and the belt fluxes are nearly inversely proportional to the belt lengths.

Effect on Belt-Flux Wave Form

An examination of Fig. 11 shows that the wave form of ϕ_i, the inner belt of flux, is flat by comparison with a sinusoid; whereas ϕ_o is peaked and ϕ_m is intermediate. It is evident

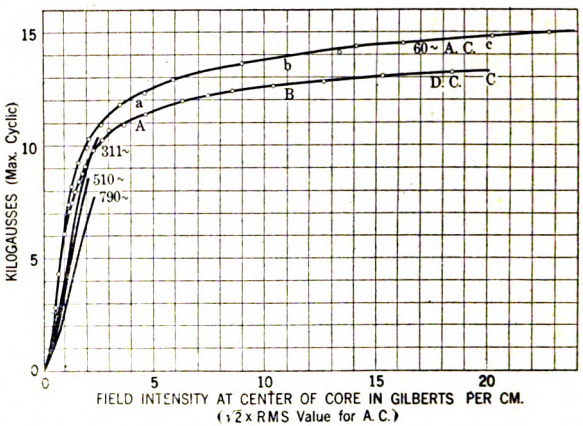


Fig. 13—Saturation Curves for x 5 Silicon Steel Obtained from a Laminated Annular Core—Inside Diameter 40.6 cm.—Outside Diameter 50.8 cm.—Laminations 0.0356 cm. Thick

that ϕ_i must be relatively flat from the curves of Fig. 6, which show that at low densities the inner belt carries an extra large share of flux, whereas towards higher densities this extra share is reduced. On the other hand, ϕ_o must be relatively peaked because the share of the outer belt increases as the density increases. In Fig. 10 the conditions are inverted, the relatively flat belt flux ϕ_i give rise to a relatively peaked e.m.f. E_i; while the peaked ϕ_o gives rises to the flattened E_o. Moreover, the exciting current has its wave form determined by the total flux in the core, or the sum of all the belt fluxes. At the lower densities existing in the outer belt, this current will be too peaked and distorted to produce a sine wave of flux; so that the outer

Digitized by Google

belt flux wave will be correspondingly peaked and distorted. The conditions are just reversed in the inner belt. This accounts for the e.m.f. wave in the outer belt being so much more irregular than in the others. Again, the inner flux, being the largest of the three, has the greatest share in determining the exciting current, and so remains the smoothest.

Saturation Curves

Fig. 13 shows the saturation curve *A B C* for the whole core of 25 laminae, as deduced from d-c. observations with a flux meter connected to an enveloping coil of six secondary turns. The upper curve *a b c* represents the corresponding saturation

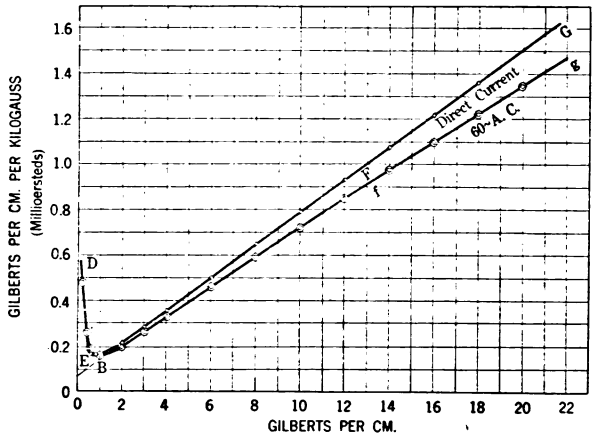


FIG. 14

with 60 ~ alternating current, multiplying the observed r.m.s. primary current by $\sqrt{2}$, to obtain the maximum cyclic magnetic intensity $\mathfrak{H}$. The observed e.m.f. per secondary turn was also multiplied by $\sqrt{2}$ to obtain the maximum cyclic kilogausses $\mathfrak{B}$. Owing to distortion of the impressed e.m.f. waves from the sinusoidal form at high flux densities, the factor $\sqrt{2}$ is evidently too low for $\mathfrak{H}$ and too high for $\mathfrak{B}$. It is supposed that if these errors did not exist, and that both $\mathfrak{H}$ and $\mathfrak{B}$ were sinusoidal quantities throughout, the curve *a b c*, would coincide with the direct-current excitation curve *A B C*.

Similar a-c. saturation curves at higher frequencies are also shown up to 7 and 9 kilogausses. It is supposed that these fall below the low-frequency curve because of skin effect.

Digitized by Google

The corresponding curves of reluctivity in the laminae, for different values of $\mathfrak{H}$, appear in Fig. 14. The reluctivity for direct currents is a rapidly descending line from 0 to 0.5 gilbert per[3] cm. It then becomes a steadily ascending straight line $F\,G$ defined by the equation $\nu = 0.000\ 07 + 0.000\ 0723\ \mathfrak{H}$ oersted-cm. The apparent reluctivity for a-c. excitation, as similarly obtained from the saturation curve $a\ b\ c$ of Fig. 13, is the curve $D\ E\ f\ g$. As before, it is supposed that if there were no errors of distortion in impressed wave form, this curve would coincide with $D\ E\ F\ G$.

It must be remembered that the reluctivity straight line $B\ E\ F\ G$ is a mean value obtained for the core as a whole.

Outline Theory of the Radial Variation

If each lamina has internal radius R_1 cm., and external radius R_2 cm. and a thickness of h cm., then the reluctance $\mathfrak{R}$ of the lamina will be, in any belt of radius r and width $d\,r$, in terms of the reluctivity ν,

$$\mathfrak{R} = \frac{\nu \cdot 2\,\pi\,r}{h \cdot d\,r} \qquad \text{oersteds (1)}$$

Under a total direct-current m.m.f. of $\mathfrak{F}$ gilberts, the flux in this belt will be

$$d\,\varphi = \frac{\mathfrak{F}}{\mathfrak{R}} = \frac{\mathfrak{F} \cdot h \cdot dr}{\nu \cdot 2\,\pi r} \qquad \text{maxwells (2)}$$

But

$$\mathfrak{F} = 2\,\pi\,r\,\mathfrak{H} \qquad \text{gilberts (3)}$$

so that

$$d\,\varphi = \frac{\mathfrak{H}}{\nu} \cdot h \cdot d\,r \qquad \text{maxwells (4)}$$

The total flux in the lamina will then be the integral of this, or

$$\phi = h \int_{R_1}^{R_2} \frac{\mathfrak{H}}{\nu}\, d\,r \qquad \text{maxwells (5)}$$

3. "Magnetic Reluctance," TRANS., A.I.E.E., Vol. 8, Oct. 27th, 1891, pp. 486-533. Also "Investigation of Magnetic Laws for Steel and other Materials," by J. D. Ball, *Journal of the Franklin Institute*, Vol. 181, April, 1916, pp. 459-504.

Digitized by Google

If ν were directly proportional to $\mathfrak{H}$, or if $\nu = b\,\mathfrak{H}$ oersted-cm,

$$\text{then} \qquad \phi = h \int_{R_1}^{R_2} \frac{d\,r}{b} = \frac{h}{b}\,(R_2 - R_1) \qquad \text{maxwells (6)}$$

This would mean uniform flux densities in all of the belt paths and the absence of all radial distortion. But the reluctivity is not directly proportional to $\mathfrak{H}$. As we have seen for this particular quality of steel, below $\mathfrak{H} = 0.5$, $\nu = 0.0007 - 0.001\,\mathfrak{H} = a_1 - b_1\,\mathfrak{H}$, and above $\mathfrak{H} = 0.5$

$$\nu = 0.000\,07 + 0.000\,0723\,\mathfrak{H} = a + b\,\mathfrak{H} \qquad \text{oersted-cm. (7)}$$

The effect of this constant term a or a_1 in the reluctivity is therefore to make the belt flux $d\,\varphi_r$ at radius r in terms of the local magnetic intensity $\mathfrak{H}_r$ and flux density $\mathfrak{B}_R$

$$d\,\varphi_r = \frac{\mathfrak{H}_r \cdot h \cdot dr}{a + b\,\mathfrak{H}_r} = h \cdot \mathfrak{B}_r \cdot d\,r = \frac{\mathfrak{F} \cdot h \cdot d\,r}{2\,\pi\,r\,a + b\,\mathfrak{F}} \qquad \text{maxwells (8)}$$

The d-c. distribution of flux density for a given value of $\mathfrak{F}$, will thus necessarily vary with r, and will tend to be greater on the inside.

We may define the flux-density distortion in a lamina as the difference between the innermost and outermost densities $\mathfrak{B}_1 - \mathfrak{B}_2$ divided by the flux density $\mathfrak{B}_R$ at the geometric mean radius R That is, if R is the geometric mean radius,

$$R = \sqrt{R_1\,R_2} = n\,R_1 = R_2/n \qquad \text{cm. (9)}$$

where n is a numerical ratio, such that $R_2 = n^2\,R_1$
It then follows from (8) that

$$\frac{\mathfrak{B}_1 - \mathfrak{B}_2}{\mathfrak{B}_R} = a\left(n - \frac{1}{n}\right) \frac{a + b\,\mathfrak{H}_R}{(a + b\,n\,\mathfrak{H}_R)\left(a + \frac{b}{n}\,\mathfrak{H}_R\right)}$$

$$= a\left(n - \frac{1}{n}\right) \frac{\nu_R}{\nu_1\,\nu_2} \qquad \text{numeric (10)}$$

Since approximately $\qquad \nu_1\,\nu_2 = \nu^2{}_R \qquad$ (oersted-cm.)^2(11)

Digitized by Google

the distortion is approximately

$$\frac{\mathfrak{B}_1 - \mathfrak{B}_2}{\mathfrak{B}_R} = \frac{a}{\nu_R}\left(n - \frac{1}{n}\right) \qquad \text{numeric (12)}$$

The quantity $$n - \frac{1}{n} = \frac{R_2 - R_1}{R} \qquad \text{numeric (13)}$$

or is the ratio of the width to the geometric mean radius of the lamina. We may call it the width-radius ratio. In the laminae tested, the width-radius ratio was $\frac{2}{\sqrt{80}} = 0.2236$. Consequently to the degree of approximation represented by (**12**), the flux-density distortion in a lamina subjected to any continuous-current m.m.f. is equal to the width-radius ratio times the ratio of the reluctivity constant a to the total reluctivity at the geometric mean belt R

If $a = 0$, the flux-density distortion disappears, as we have already seen.

If $b = 0$, so that the reluctivity is independent of the excitation, (**12**) becomes $\frac{\mathfrak{B}_1 - \mathfrak{B}_2}{\mathfrak{B}_R} = \left(n - \frac{1}{n}\right)$, or the distortion is numerically equal to the width-radius ratio.

As ν_R increases, with increasing flux density, towards saturation, the ratio a/ν_R becomes very small, and the distortion nearly disappears.

On the ascending straight line of reluctivity, above $\mathfrak{H} = 0.5$, in the case considered, a/ν_R is always less than unity, or the distortion to continuous m.m.f. is always less than the width-radius ratio.

On the initial descending straight line of reluctivity, below $\mathfrak{H} = 0.5$ in the case considered, a/ν_R is likely to exceed unity, so that over this range of $\mathfrak{H}$, the distortion is likely to be greater than the width-radius ratio, and, in particular cases, may be several times greater.

In order to prevent the existence of all distortion, the width-radius ratio must be reduced to zero, which means that the lamina must be cut from a cylinder, instead of from a flat sheet of metal. In the ordinary case of a flat annular stamping, the distortion diminishes as the mean radius is increased. When it

Digitized by Google

is desired to measure the magnetic properties of the steel with considerable precision, the width-radius ratio should be kept as small as possible, otherwise the mean apparent permeability of the steel at any given intensity $\mathfrak{H}$, as derived from the joint behavior of all the belts in parallel, will differ from the true permeability in any one belt. The error tends to be greatest at low densities referred to the descending branch of the $\nu - \mathfrak{H}$ graph, and diminishes towards high densities.

The authors are indebted to the American Telephone and Telegraph Co., under an appropriation from which the investigation was carried on. They are also indebted to Prof. C. A. Adams and to Mr. R. Eksergian, for valuable suggestions during the work.

Conclusions

(1) As has already been noted by several writers, the flux density differs in different belts of an annular steel lamina, under a circumferential impressed m.m.f. from a distributed toroidal winding. The phenomenon may be described as radial distortion of flux density.

(2) The distortion occurs both with continuous and alternating m.m.fs. It may be very marked at low densities. At high frequencies, flux-density distortion is complicated by skin effects.

(3) With alternating m.m.fs., a distortion is effected in the alternating magnetic wave form, as well as in the maximum cyclic flux density. Each belt has its own density, and its own wave form. The total flux in the lamina being, say, sinusoidal, the individual belt fluxes will be nonsinusoidal. The external belt fluxes have, in general, the most distorted wave forms.

(4) The magnitude of flux-density distortion may be defined as the difference between the inside and outside flux densities, divided by the flux density at the geometrical mean radius. In the case reported, the observed a-c. flux-density distortion was approximately $\frac{0.45 - 0.24}{0.31} = 0.68$, at low densities.

(5) The magnitude of flux-density distortion depends upon the width-radius ratio of the lamina, or the width of the lamina divided by its geometrical mean radius. In the case reported, this ratio was 0.224. The smaller this ratio, other things being equal, the less the distortion.

(6) For a given width-radius ratio, the flux-density distortion depends, to a first approximation, on the ratio a/ν of the constant

Digitized by Google

reluctivity term a to the total reluctivity ν in the geometric mean belt. Over the ascending straight range of the reluctivity-intensity $\nu - \mathfrak{H}$ graph, this ratio is less than unity, so that, at least in the continuous-current case, the distortion will be less than the width-radius ratio over this range (above $\mathfrak{H} = 1$ in the case reported.) On the descending branch of the $\nu - \mathfrak{H}$ graph, the ratio a/ν will be greater than unity, so that at low values of $\mathfrak{H}$ and $\mathfrak{B}$, the distortion is likely to exceed the width-radius ratio (below $\mathfrak{H} = 1$, $\mathfrak{B} = 6000$ in the case reported).

(7) When the magnetic characteristics of steel laminae are to be measured with precision, small width-radius ratios should be used, in order to avoid errors due to flux-density distortion. Strictly speaking, curves derived from annular laminae are all subject to distortion errors, especially at low densities.

(8) The eddy-current losses occurring in annular laminae under sinusoidal a-c. excitation are exaggerated by the presence of harmonics in the various belt fluxes.

List of Symbols Employed

a, b	Reluctivity constants for a sample of steel.
$\mathfrak{B}$	flux density in steel, (gausses, or maxwells per sq. cm.)
$\mathfrak{B}_{max}$	maximum cyclic flux density in steel (gausses).
$\mathfrak{B}_i$ $\mathfrak{B}_m$ $\mathfrak{B}_o$	flux densities in inner, middle, and outer belts of a lamina (gausses) and in alternating-current cases maximum cyclic gausses.
$\mathfrak{B}_t$	flux density in a lamina averaged over the entire cross section (gausses and in alternating-current cases maximum cyclic gausses).
$\mathfrak{B}_1$ $\mathfrak{B}_2$ $\mathfrak{B}_R$	flux density at inner edge, at outer edge, and at geometric mean belt of a lamina, respectively (gausses, and in a-c. cases, maximum cyclic gausses).
E	electromotive force induced in a winding (volts).
$\mathfrak{F}$	magnetomotive force applied to a lamina circumferentially (gilberts or c. g. s. magnetic units).
$\mathfrak{H}$	magnetic intensity or magnetic force in steel (gilberts per cm.)
$\mathfrak{H}_r$	magnetic intensity in a lamina at belt of radius r (gilberts per cm.)
h	width of a lamina measured along any radius (cm.)

Digitized by Google

n ratio of geometric mean radius to inner radius of an annular lamina (numeric).

$\nu = a + b\mathfrak{B}$ reluctivity of steel (oersted-cm.)

ν_1, ν_2, ν_R reluctivity at inner, outer, and geometric mean belts of a lamina, respectively (oersted-cm.)

ϕ total magnetic flux in a lamina (maxwells).

ϕ_r magnetic flux in a belt of a lamina at radius r (maxwells).

ϕ_i, ϕ_m, ϕ_o magnetic fluxes in the inner, middle, and outer belts of an annular lamina, respectively (maxwells).

$\mathfrak{R}$ reluctance of a belt path (oersteds.)

r radius of an annular belt (cm.)

R_1, R_2 internal and external radii of an annular lamina (cm.)

$R = \sqrt{R_1 R_2}$ geometric mean radius of an annular lamina (cm.)

Σ summation sign, $\angle$ angle sign, $\sim$ sign for cycles per second.

Digitized by Google

Digitized by Google

PROCEEDINGS

OF THE

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

INDEX TO VOLUME XXXVI

JANUARY 1 TO DECEMBER 31, 1917

INDEX OF SUBJECTS

A. I. E. E. Honor Roll.....*December* 298
A. I. E. E. Nominations.....*April,* 92
A. I. M. E. New York Meeting.....*February,* 34
Accessions to United Engineering Society, Library, *January,* 24; *February,* 52; *March,* 78; *April,* 110; *May,* 143; *June,* 171; *July,* 195; *August,* 214; *September,* 234; *October,* 252; *November,* 282; *December,* 316
Address by President-Elect E. W. Rice, Jr.....*August,* 635
Alternating Current Generators Internal Temperatures of, (Ralph Kelly).....*February,* 103
Amendment to By-Laws.....*May,* 124
Analysis of Starting Characteristics of D-C. Motors, (K. L. Hansen) *February,* 255
Annual Business Meeting and Edison Medal Presentation...*May,* 123
June, 156
Annual Load Relief Map, Peak Load, and Load Factor Analysis (Wm. Le Roy Robertson).....*December,* 941
Annual Meeting of A. S. M. E.....*December,* 295
Annual Meeting of Society of Automobile Engineers.....*January,* 5
Annual Report of Technical Committees.....*July,* 589
Applications for Election, *January,* 20; *February,* 45; *March,* 74; *April,* 106; *May,* 140; *June,* 170; *July,* 193; *August,* 212; *September,* 233; *October,* 251; *November,* 278; *December,* 314
Artificial Power Transmission Line for The Telluride Power Company of Provo, Utah, Design, Construction and Tests of an (George H. Gray).....*September,* 713
Associates Elected, *January,* 17; *February,* 40; *March,* 71; *April,* 100; *May,* 132; *June,* 163; *July,* 188; *September,* 229; *November,* 275; *December,* 313
Associates Re-elected, *April,* 100; *May,* 139; *June,* 168; *July,* 192; *November,* 277
Board of Directors Report for Fiscal Year ending April 30, 1917, *June,* 549
Cable Joints, Fundamentals of High Tension, (D. W. Roper).*June,* 441
Cables, Insulation Characteristics of High-Voltage, (W. S. Clark and G. B. Shanklin).....*June,* 465
Cables, Problems of Operation and Maintenance of Underground, (John L. Harper).....*May,* 409

Digitized by Google

Cables, The Influence of Dielectric Losses on the Rating of High-Tension Underground, (A. F. Bang and H. C. Louis).....*June*, 449
Ceramics in Relation to the Durability of Porcelain Suspension Insulators (Harris J. Ryan).....*January*, 61
Conventions
Annual.....*March*, 61; *April*, 90; *May*, 123
Midwinter.....*January*, 2; *February*, 31; *March*, 65
Cooling of Oil Immersed Transformer Windings after Shut-Down, (V. M. Montsinger).....*April*, 351
Corona and Rectification in Hydrogen, (J. W. Davis and C. S. Breese).....*February*, 143
Corona Tests at High Altitude, (B. F. Jakobsen).....*December*, 941
Design, Construction and Tests of an Artificial Power Transmission Line for the Telluride Power Company of Provo, Utah, (George H. Gray).....*September*, 713
Dinner to President-Elect Rice.....*July*, 183
Direct-Current Motors, Analysis of Starting Characteristics of, (K. L. Hansen)..... *February*, 255
Direct-Current Motors, Industrial Controllers with Particular Reference to the Control of (H. D. James).....*February*, 233
Economical Combination of Water Power and Steam Plants, and a Convenient Method of Solution, (H. St. Clair Putnam).*June*, 531
Effect of Current-Limiting Reactors in Steam Turbine Stations Under Short Circuit Conditions, (Paul B. Juhnke)...*February*, 281
Electric Strength of Air, VII, The (J. B. Whitehead and W. S. Brown).....*February*, 159
Electrical Engineers Nominated for Commissions in Navy, *November*, 271
Electrical Machinery Tests and Specifications Based on Modern Standards, (H. M. Hobart).....*March*, 291
Electrostatic Problems, with Notes on High Voltage Bushing Design, an Experimental Method of Obtaining the Solution of, (C. W. Rice).....*November*, 777
Employment Bulletin, *January*, 22; *February*, 49; *March*, 80; *April*, 111; *May*, 144; *June*, 173; *July*, 202; *August*, 220; *September*, 238; *October*, 254; *November*, 285; *December*, 320
Engineering Council, The, *June*, 158; *September*, 228; *October*, 247; *November*, 273
Engineering Foundation and the National Research Council, The, *November*, 263
Engineering Societies Club of Hawaii.....*December*, 297
Engineering Societies in National Defense, The, (Gano Dunn) *May*, 124
Engineer's Destiny, The, President's Address, (H. W. Buck) *August*, 629
Engineers in National Defense.....*March*, 62
Examination for Assistant Civil Engineer, United States Navy, *October*, 250
Expansion Effects as a Cause of Deterioration in Suspension Type Insulators, (J. A. Brundige).....*May*, 391
Experimental Method of Obtaining the Solution of Electrostatic Problems with Notes on High Voltage Bushing Design, (C. W. Rice).....*November*, 777
Experiments on Porcelain Insulator Units (J. Cameron Clark) *January*, 77
Fellows Elected.....*June*, 169; *July*, 192
Florida Engineering Society.....*February*, 37; *August*, 211
Flux Distribution in Annular Steel Laminae, Magnetic, (A. E. Kennelly and P. L. Alger).....*December*, 999
Forms of Electric Power Best Suited for the Various Loads Encountered in the Operation of Bituminous Coal Mines, (R. L. Kingsland).....*July*, 567
Fundamentals of High Tension Cable Joints, (D. W. Roper).*June*, 441

Digitized by Google

Future Institute Meetings.....*January*, 4; *February*, 33
Future of Water Power in the United States, The, (Charles W. Comstock).....*January*, 91
Future Section Meetings, *January*, 4; *February*, 33; *March*, 61; *April*, 90; *May*, 127; *November*, 273; *December*, 296
Greetings from French Engineers.....*May*, 126
Greetings from the Institution of Electrical Engineers.....*July*, 183
Government Service.....*November*, 272
High-Tension Lines, Relays, for, (Philip Torchio).....*March*, 321
Hoist, New Electric Mine, at Butte Mont., (R. S. Sage)....*July*, 573
Hydroelectric Stations, Reactors in, (J. Allen Johnson)..*February*, 119
Illuminating Engineering Society Meeting.....*November*, 271
Illumination of Panama-Pacific International Exposition, (W. D'A. Ryan).....*June*, 415
Induction Motors Under Unbalanced Secondary Conditions, Performance of Polyphase, (A. Gazda).....*February*, 223
Industrial Controllers with Particular Reference to the Control of D-C. Motors, (H. D. James).....*February*, 233
Industrial Research and Its Relation to University and Governmental Research, (C. E. Skinner).....*October*, 765
Industrial Research and the Colleges, (A. E. Kennelly)...*October*, 757
Industrial Research with Some Notes Concerning Its Scope in the Bell Telephone System (F. B. Jewett).....*November*, 925
Influence of Dielectric Losses on the Rating of High-Tension Underground Cables, The, (A. F. Bang and H. C. Louis).*June*, 449
Insulation Characteristics of High-Voltage Cables, (W. S. Clark and G. B. Shanklin).....*June*, 465
Insulator Deterioration, Investigation of Suspension, (J. E. Woodbridge).....*January*, 57
Insulator Situation, The, (W. D. Peaslee).....*May*, 401
Insulator Units, Experiments on Porcelain, (J. Cameron Clark) *January*, 77
Insulators, Ceramics in Relation to the Durability of Porcelain Suspension, (Harris J. Ryan).....*January*, 61
Insulators, Expansion Effects as a Cause of Deterioration in Suspension Type, (J. A. Brundige).....*May*, 391
Insulators, Present Practise in the Design and Manufacture of High Tension, (A. O. Austin).....*June*, 513
Internal Temperatures of A-C. Generators, (Ralph Kelly) *February*, 103
Investigation of Suspension Insulator Deterioration, (J. E. Woodbridge).....*January*, 57
John Fritz Medal.....*February*, 34
John Fritz Medal Book.....*April*, 95
Library Director, Harrison W. Craver, Appointed.....*April*, 94
Report for 1916.....*April*, 94
Load Relief Map, Peak Load, and Load Factor Analysis, Annual, (Wm. Le Roy Robertson).....*December*, 941
Magnetic Flux Distribution in Annular Steel Laminae, (A. E. Kennelly and P. L. Alger).....*December*, 999
Meeting of Institute of Radio Engineers.....*December*, 296
Meetings,
A. I. E. E. Regular
Boston, December 9, 1916.....*January*, 5
Pittsburgh, Pa., January 12, 1917.....*January*, 1; *February*, 37
Chicago, March 9, 1917.....*March*, 59; *April*, 91
Schenectady, April 13, 1917.....*March*, 61; *April*, 89
New York May 18, 1917.....*April*, 90
Philadelphia, October 8, 1917, *September*, 227; *October*, 247; *November*, 267 *December*,
New York, November 9, 1917.....*November*, 263
New York, December 14, 1917.....*December*, 295

Digitized by Google

Branch, *January*, 14; *February*, 38; *March*, 68; *April*, 97; *May*, 130; *June*, 162; *July*, 187; *November*, 274; *December*, 310
Directors, *January*, 4; *February*, 34; *March*, 62; *April*, 91; *May*, 128; *June*, 159; *July*, 182; *September*, 227; *November*, 268; *December*, 306
Section, *January*, 12; *February*, 37; *March*, 67; *April*, 95; *May*, 128; *June*, 161; *July*, 186; *August*, 211; *September*, 228; *October*, 250; *November*, 273; *December*, 309
Members Elected, *January*, 17; *February*, 40; *March*, 70; *April*, 99; *May*, 138; *June*, 168; *July*, 192; *September*, 232; *November* 277; *December*, 313
Members Re-Elected ..... *April*, 100; *May*, 139
Membership Service Classification ..... *December*, 306
Memorial to the Late Prof. Silvanus P. Thompson ..... *May*, 126
Mine Hoist at Butte, Mont., A New Electric, (R. S. Sage) ..... *July*, 573
Mines, Forms of Power Best Suited to the Various Loads Encountered in the Operation of Bituminous Coal, (R. L. Kingsland) *July*, 567
Modern Physics (R. A. Millikan) ..... *September*, 695
National Committee on Gas and Electric Service, ... *July*, 184
New Cooperative Courses at M. I. T. ..... *October*, 250
New Electric Mine Hoist at Butte, Mont., A, (R. S. Sage) .. *July*, 573
Nominations for Institute Officers for 1917-1918 ..... *January*, 3
Obituary, *April*, 109; *May*, 142; *July*, 194; *August*, 213; *October*, 252
Oscillating Current Circuits by the Method of Generalized Angular Velocities, (V. Bush) ..... *February*, 189
Panama-Pacific International Exposition, Illumination of, (W. D'A. Ryan) ..... *June*, 415
Performance of Polyphase Induction Motors Under Unbalanced Secondary Conditions, (A. Gazda) ..... *February*, 223
Personal, *January*, 16; *February*, 48; *March*, 77; *April*, 109; *May*, 142; *June*, 171; *July*, 194; *August*, 213; *September*, 234; *October*, 251; *November*, 280; *December*, 316
Phenomena Accompanying Transmission with some Types of Star Transformer Connections, II, (L. N. Robinson) .. *December*, 967
Physics, Modern, (R. A. Millikan) ..... *September*, 695
Polyphase Induction Motors Under Unbalanced Secondary Conditions, Performance of, (A. A. Gazda) ..... *February*, 223
Present Practise in the Design and Manufacture of High Tension Insulators, (A. O. Austin) ..... *June*, 513
Presentation of the John Fritz Medal ..... *January*, 6
Presentation of the John Fritz Medal to Henry Marion Howe, *July*, 185
Problem of Selecting Papers, The, (L. T. Robinson) ..... *May*, 127
Problems of Operation and Maintenance of Underground Cables, (John L. Harper) ..... *May*, 409
Protection of Transformer Neutrals against Destructive Transient Disturbances, (Max H. Collbohm) ..... *February*, 139
Protective Relay Equipment of the System of the Commonwealth Edison Company, The, (R. F. Schuchardt) ..... *March*, 337
Reactors in Hydroelectric Stations, (J. Allen Johnson) .. *February*, 119
Reactors in Steam Turbine Stations Under Short Circuit Conditions, The Effect of Current Limiting, (Paul B. Juhnke) *February*, 281
Reception to the American Society of Civil Engineers .. *December*, 296
Recommended for Transfer, *January*, 16; *February*, 40; *March*, 71; *April*, 105; *May*, 139; *June*, 169; *July*, 192; *August*, 212; *September*, 232; *October*, 251; *November*, 277; *December*, 314
Regenerative Braking of Electric Vehicles, (R. E. Hellmund) *January*, 1
Reinstated to Membership ..... *March*, 70
Relay Equipment of the System of the Commonwealth Edison Company, the Protective, (R. F. Schuchardt) *March*, 337

Digitized by Google

Relays for High Tension Lines, (Philip Torchio).....*March*, 321
Report of Committee of Tellers on Election,.....*June*, 157
Report of Committee of Tellers on Nomination Ballots....*April*, 92
Report of the Joint Rubber Insulation Committee.....*April*, 371
Research Fellowships, University of Illinois.....*January*, 12
Rules Governing Presentation and Discussion of Papers at Institute Meetings.....*June*, 160
Scope of Future Meetings to be Extended.....*December*, 296
Special Meeting of A. I. E. E., New York, June 27-28, 1917, *June*, 155; *July*, 181
Steam Plants, Economical Combination of Water Power and, a Convenient Method of Solution, (H. St. Clair Putnam)..*June*, 531
Stott, Henry Gordon.....*February*, 35
Students Enrolled, *January*, 21; *February*, 47; *March*, 76; *April*, 108 *May*, 141; *June*, 171; *July*, 194; *September*, 233; *November*, 279; *December*, 315
Technical Committees, Annual Report of,.....*July*, 589
Third National Exposition of Chemical Industries.....*July*, 186
Transferred to the Grade of Fellow, *January*, 17; *April*, 106; *May*, 140; *June*, 169; *July*, 193; *September*, 232; *November*..... 277
Transferred to the Grade of Member, *January*, 17; *February*, 40; *March*, 70; *April*, 106; *May*, 140; *June*, 169; *July*, 193; *September*, 232; *November*, 278; *December*, 313
Transformer Connections, II, Phenomena Accompanying Transmission with Some Types of Star, (L. N. Robinson)..*December*, 467
Transformer Windings After Shutdown, Cooling of Oil Immersed (V. M. Montsinger).....*April*, 351
Transient Conditions in Asynchronous Induction Machines and Their Relation to Control, (R. E. Hellmund).....*February*, 205
Transmission Line Design (F. K. Kirsten).....*August*, 641
Transmission Line for the Telluride Power Company of Provo, Utah, Design, Construction and Tests of an Artificial Power, (George H. Gray).....*September*, 713
Topographical Map of the United States.....*January*, 12
United Engineering Society, Extracts from President's Annual Report.....*April*, 93
Valuable Gift to Library.....*June*, 160
Water Power and Steam Plants, Economical Combination of, and a Convenient Method of Solution, (H. St. Clair Putnam).*June*, 531
Water Power in the United States, The Future of, (Charles W. Comstock).....*January*, 91
Work of Meetings and Papers Committee, The.....*November*, 269
Year Book, 1917.....*February*, 34

INDEX OF AUTHORS

Alger, P. L.....*December*, 999
Austin, A. O.....*June*, 513
Bang, A. F.....*June*, 449
Breese, C. S.....*February*, 143
Brown, W. S.....*February*, 159
Brundige, J. A.....*May*, 391
Buck, H. W.....*August*, 629
Bush, V.....*February*, 189
Clark, J. Cameron.....*January*, 77
Clark, W. S.....*June*, 465
Collbohm, Max H.....*February*, 139
Comstock, Charles W.....*January*, 91
Davis, J. W.....*February*, 143
Gazda, A. A.....*February*, 223
Gray, George H.....*September*, 713
Hansen, K. L.....*February*, 255

Digitized by Google

Harper, John L. ..... *May*, 409
Hellmund, R. E. ..... *January*, 1; *February*, 205
Hobart, H. M. ..... *March*, 291
Jakobsen, B. F. ..... *December*, 949
James, H. D. ..... *February*, 233
Jewett, F. B. ..... *November*, 925
Johnson, J. Allen ..... *February*, 119
Juhnke, Paul B. ..... *February*, 281
Kelly, Ralph ..... *February*, 103
Kennelly, A. E. ..... *October*, 757; *December*, 999
Kingsland, R. L. ..... *July*, 567
Kirsten, F. K. ..... *August*, 641
Louis, H. C. ..... *June*, 449
Millikan, R. A. ..... *September*, 695
Montsinger, V. M. ..... *April*, 351
Peaslee, W. D. ..... *May*, 401
Putnam, H. St. Clair ..... *June*, 531
Rice, C. W. ..... *November*, 777
Rice, E. W., Jr. ..... *August*, 635
Robertson, William Le Roy ..... *December*, 941
Robinson, L. N. ..... *December*, 967
Roper, D. W. ..... *June*, 441
Ryan, Harris J. ..... *January*, 61
Ryan, W. D'A. ..... *June*, 415
Sage, R. S. ..... *July*, 573
Schuchardt, R. F. ..... *March*, 337
Shanklin, G. B. ..... *June*, 465
Skinner, C. E. ..... *October*, 765
Torchio, Philip ..... *March*, 321
Whitehead, J. B. ..... *February*, 159
Woodbridge, J. E. ..... *January*, 57

Digitized by Google

260 Pages 7x10 180 Illustrations 7 Plates NET $5.00

Large Electric Power Stations

THEIR DESIGN AND CONSTRUCTION

With Examples of Existing Stations

BY DR. G. KLINGENBERG

This English translation of "Bau grosser Elektrizitätswerke" covers a field hitherto untouched. While it is almost excessively modern in selection of topics discussed, it deals more than any other book on the subject with fundamental principles of power plant design and organization. It is a safe guide for the broad outlines of a power station project, rather than a text-book for the draftsman. It will make its appeal to the higher type of engineers who must include financial factors in their computations.

The entire analysis is founded on the load curve. From this there are developed two new diagrams—the "steam consumption characteristic" and the "economic characteristic." The former shows the steam consumed per hour and the latter the generating cost, both on a load base. Both curves are approximately straight lines intersecting the coordinate axis at a distance from the origin.

Special topics of immediate interest are discussed in chapters on individual economizers, increased steam velocities in pipes, large generating units, high vacuum apparatus, switching plant, generator cooling and steam vs. motor-driven auxiliaries. The practice referred to is that of continental Europe. Pressures and superheats there regarded as standard are now indentical with those used by progressive designers in this country, and various underlying factors are thought by experts to be drawing American power-station engineers into close alignment with practice abroad. For this reason, the Klingenberg book is especially timely. It contains comprehensive illustrations and descriptions of several recent plants designed by the author. There is an authoritative chapter on architectural features, not paralleled elsewhere.

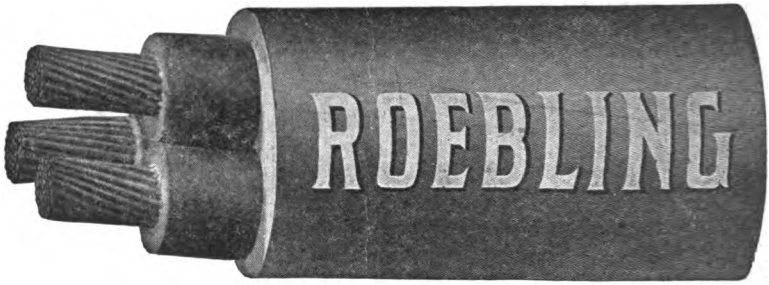
Not the least suggestive sections of the book are those devoted to a basic discussion of transportation costs for coal as compared with those for power, and to an analysis of the process of predetermining rates for the sale of electricity for any given case. In this last connection a review of legislative tendencies and municipal ownership is included.

D. Van Nostrand Company

Publishers and Booksellers

25 PARK PLACE NEW YORK

Digitized by Google



WIRES and CABLES

Aerial Cables
Annunciator Wire
Annunciator Cables
Automobile Horn Cord
Automobile Lighting Cables
Automobile Starter Cables
Automobile Charging Cables
Automobile Ignition Cables
Armature Coils
Armature Leads
Asbestos Braided Wire
Brush Cables
Border Light Cables
Brewery Cord
Battery Wire
Bridle Wire
Bare Copper Wire
Bare Copper Strands
Bare Braided Copper
Copper Wire, Bare
Copper Strands, Bare
Charging Cable for Electric Vehicles
Copper Clad, Rubber Insulated
Copper Clad Weatherproof
Cambric Cables
Canvasite Cord
Control Cable For Elevators
Car Wire And Cables
Cotton Tubing or Sleeving
Copper Sleeves
Copper Bells
Compound, Pothead No. 1
Compound, Splicing No. 2
Compound, Telephone No. 3
Drop Wire
Deck Cables
Electric Horn Cord
Electric Vehicle, Charging Cables
Electric Locomotive Cables
Elevator Annunciator Cables
Elevator Lighting Cables
Elevator Control Cables
Enameled Wire
Fixture Wire
Fireproof Wires
Flameproof Wire
Fire and Weatherproof Wire
Field Coils
Friction Tape
Gas Fixture Wire
Gas Engine Cables
Heater Cord
Ignition Cables
Interior Telephone Wire
Insulating Paper
Insulating Tape
Jumper Wire
Lamp Cord
Lighting Cable, Automobile
Locomotive Cables, Mine
Moving Picture Cord
Messenger Strand
Mining Machine Cables
Motor Lead Cable
Magnet Wire
Motor Boat Wires and Cables
Motorcycle Wires and Cables
Office Wire and Cables
Oilproof Finishing Braids
Power Cable, Rubber Insulated
Power Cable, Cambric Insulated
Power Cable, Paper Insulated
Packing House Cord
Paraffine Wax
Rubber Covered Wire, N. E. C. S
Rubber Tape
Starter Cables
Sweeper Cord
Spider Wire
Stage Cables
Signal Wire and Cables
Submarine Cable
Switchboard Wire
Switchboard Cords
Switchboard Cable
Slow Burning Wire
Solenoids
Secondary Spark Coils
Silk Tubing or Sleeving
Telephone Cords
Telephone Wire
Telephone Cable, Paper Insulation
Telephone Cable, Rubber Insulation
Tubing, Cotton and Silk
Telegraph Wire
Telegraph Cable, Paper Insulation
Telegraph Cable, Rubber Insulation
Vacuum Cleaner Cord
Vibrator Cord
Weatherproof Wire

John A. Roebling's Sons Co.

TRENTON, N. J.

BRANCHES:

New York Boston Chicago Philadelphia Pittsburgh Cleveland
Atlanta San Francisco Los Angeles Seattle Portland, Ore.

Digitized by Google

Digitized by Google

Digitized by Google

Digitized by Google

32101 048906307

Digitized by Google